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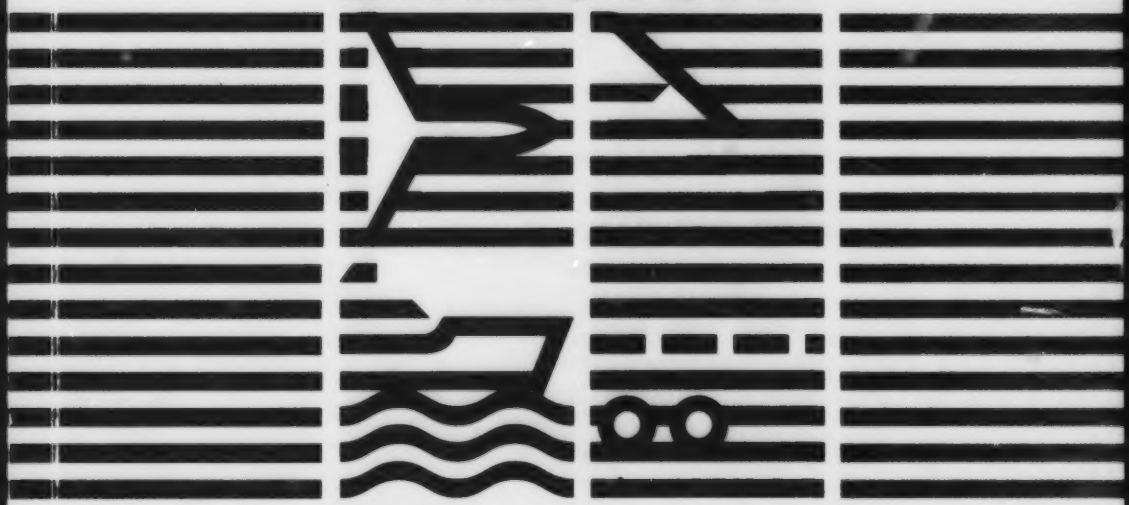
TDC PROJECT DIRECTORY



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11th edition

Transport Canada Transports Canada

Transportation Development Centre
Policy and Coordination Group

Canada

TDC Project Directory

Transportation Development Centre
Policy and Coordination Group
Transport Canada

11th edition

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Minister
Transport Canada

Ministre
Transports Canada

An effective transportation system, providing essential services for industry and travellers, is vital to Canadians and to the Canadian economy. In the nineties an increasingly competitive international economy will intensify demands for safe, reliable, and efficient transportation.

Transport Canada's Transportation Development Centre (TDC) is helping to meet this challenge through its long-term program of transportation research and development.

TDC works closely with other federal departments, the provinces, industry, and universities to research and develop sophisticated technology in all modes, as well as undertaking projects concerning transportation accessibility and environmental protection. This directory documents the success of this cooperative approach.

TDC celebrated its twentieth anniversary in 1990. While it has undergone many changes in meeting the challenges of the past two decades, its mandate remains the same — to develop technologies in support of the Canadian transportation network. We are confident that it will continue to keep Canada at the leading edge of transportation technology in the years to come.

The Honourable Doug Lewis
Minister of Transport

PREFACE

This is the eleventh edition in a series of project directories describing the research and development activities of Transport Canada's Transportation Development Centre (TDC). This edition presents a selection of projects active between January 1989 and June 1990. The five chapters – marine, air, highway, rail, and accessible transportation – represent TDC's principal areas of research.

Each description outlines a project's rationale, objectives, and methodology, as well as its outcome or current status, and gives the performing organization, project schedule, and funding sources. A list of recently published reports is included at the end of the directory.

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INTRODUCING TDC

The Transportation Development Centre (TDC), established in Montreal in 1970, serves as Transport Canada's centre of expertise for transportation research and development. Organized into five research divisions, the centre's staff of engineers, ergonomists, planners, and economists initiates, manages, and reports on an average of 300 projects a year. Funded largely on a cost-shared basis with other Transport Canada components, other federal departments and levels of government, and industry, projects are contracted to a variety of organizations, mostly in the private sector, and cover all transportation modes, systems, and technologies.

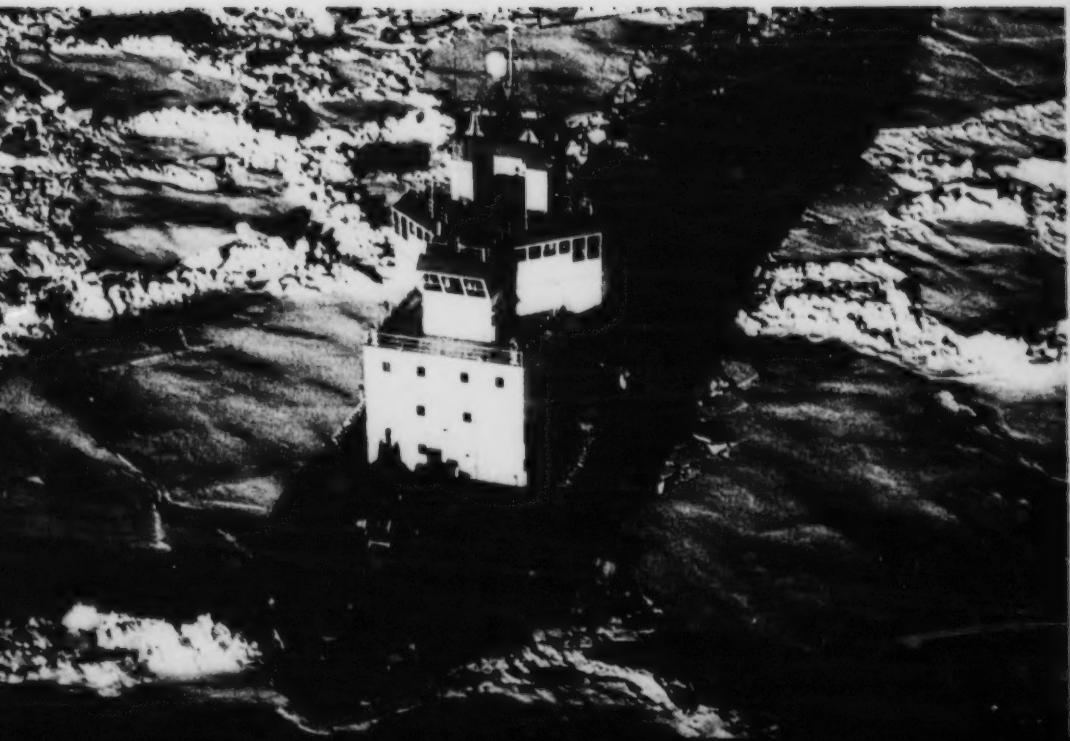
A part of the Research and Development Directorate of the Policy and Coordination Group, TDC is responsible for implementing the department's Central Research and Development (R&D) Program. The cornerstone of this Program is the Core R&D Policy, which provides for a sustained commitment to research and development designed to meet the needs of the department and the transportation sector through: **exploratory R&D**, concerning generic or enabling transportation technologies and the application of strategic or emerging technologies to transportation; **long-term applications R&D**, entailing the development of innovative technological methods to improve operations, regulations, and capital procurement; and **sector-directed R&D**, addressing safety, productivity, system competitiveness, and environmental factors.

An R&D Council chaired by the Director General, Research and Development, helps TDC implement these activities by providing advice on federal as well as departmental objectives and priorities. Its members represent Transport Canada's operating groups, including Airports, Aviation, Marine, Surface, and Security and Emergency Planning. In addition, TDC consults with its partners in the R&D community through modal advisory boards that help to define objectives, review technical work, and implement projects.

In addition to research activities in support of the Core R&D Policy, TDC is involved in the following special programs: Transportation for Disabled Persons Program (TDPP) of Transport Canada; the federal Energy Research and Development Program; and the Canada-Quebec Economic and Regional Development Agreement on Transportation Development.

TDC's work is supported by an active publications division and an extensive transportation technology library. The publications division releases an average of 130 titles a year, including project research reports and general information materials on TDC's research program. The Judith Nogrady Library collection comprises 18 000 books and reports, 450 periodical titles, and a growing audiovisual section. It has access to holdings of other Canadian libraries through its participation in the Utlas automated cataloguing system.

MARINE TRANSPORTATION



MARINE TRANSPORTATION

TDC's marine R&D program centres on the design, regulation, and safe operation of vessels in Canadian waters. The program emphasizes the development of technologies aimed at making shipping safer in icebound waters and extending the shipping season in Canada's southern waters, as well as the evaluation of new products and systems in support of the Canadian Coast Guard (CCG).

Regulation and Safety

The regulation and safety program addresses Arctic and conventional ships, search and rescue, marine safety, and environmental protection. Transport Canada's prime function in this area is to ensure that the marine transportation system is as safe as possible. This program supports the Canadian Arctic Shipping Pollution Prevention Regulations (CASPPR), which protect Canada's sensitive northern ecosystem. The regulatory regime must strike a balance between protecting the northern environment and facilitating commercial operations in the Arctic.

The results of research to develop safer and more efficient propulsion systems for CCG icebreakers can be applied to new and existing ship infrastructures, and, where appropriate, to CASPPR. Current activities focus on improved mathematical models of propulsion trains to predict shaft line and propeller reactions of ships operating in ice.

The CCG is responsible for the provision of safe and efficient search and rescue services. Improved response time through the introduction of new technology can save lives, as well as reduce the costs of these services. TDC's principal effort is directed toward understanding drift patterns and improving detection techniques.

Protection of the environment is a recent research initiative for TDC. As Transport Canada is responsible for preserving the Canadian marine environment, it must minimize the risk of pollution and respond quickly to any threatening incident. TDC is now investigating the detection and tracking of surface or submerged oil spills.

Performance Prediction in Ice

Research into ship performance in ice is a continuing priority. Hull forms and power plants must be designed to allow ships to operate adequately in level ice as well as in ice ridges.

Modelling techniques for propeller-ice interaction and ridge-breaking capability are being explored to help determine the power levels required to break ice of varying thicknesses and strengths. Methods for correlating model ice resistance with full-scale data are also under study.

Improvements to Icebreaking Ships

Efficient icebreaking ships are required for the varied manoeuvres and ice conditions associated with Arctic operations. Safe transportation is particularly important, given the sensitive environment. Research is concentrated on the performance of various hull forms, the improvement of analytical models, the investigation of stern appendages, and the synthesis of design data from various commercial and CCG icebreakers. Studies on the optimization of Arctic tanker hull forms, coupled with analyses of the effect of the length-to-beam ratio on ship resistance in ice, will aid in the development of the next generation of ice-capable cargo ships.

Navigation Technology

Canada leads the world in the development of ice navigation technology essential for year-round commercial shipping in the Arctic. The Shipboard Integrated Navigation Support System (SINSS), developed during five years of TDC-supported work, is the world's first commercial ice navigation system.

Electronic charts and navigation displays are revolutionizing ship navigation in coastal waters, confined rivers and lakes, and ports. TDC's R&D effort has largely centred on improving the navigation computers, electronic charts, and displays that are common to all navigation systems, regardless of the method used to determine ship location. Recent activities have centred on the development of advanced electronic displays and the superimposition of radar data on navigation charts.

Ship Automation and Human Factors

The marine automation and control program comprises three technology developments: advanced ship control systems, shipboard predictive maintenance capability, and intra-vessel communication networks. Research on ship automation and control can directly affect ship operating costs by reducing maintenance expenses and minimizing crewing requirements. Research efforts are concentrating on developing new computer and communications technologies with a view to integrating ship systems and assisting in the shift from scheduled ship maintenance to a preventive program. Studies in human factors affecting crewing will lead to more effective use of personnel.

Shaftline and nozzle dynamics in ice

Icebreaking ships are subject to nozzle blockage by ice. Previous research detected that ice interaction with the propeller produced significant variations in thrust, torque, and bearing loads. This project investigated the magnitude of these variations and their effects on shaft dynamics when a propeller is protected by a nozzle. The objective was to obtain both quantitative and qualitative understanding of the complete shafting, nozzle, and bearing system response to dynamic ice loads. This understanding, together with the data available from other vessels, will support the development of regulatory requirements and dynamic modelling techniques for predicting component loading of the propulsion system in the design of icebreaking vessels.

Full-scale propulsion system tests were conducted on the Class 4 icebreaker MV *Ikaluk*. Unique instrumentation was developed and installed for the dynamic measurement of the complete port shafting system, including the nozzle response to ice loads.

The system functioned as planned and extensive data were acquired in an easily accessible format suitable for computer-aided processing and analysis. The data contain many sets of quantitative results relating shaft torque and thrust response to shaft movements and bearing reactions. The quantification of the thrust contribution of the nozzle is a particularly useful aspect of the system.

Contractor: Fleet Technology Ltd., Calgary, Alberta

Report: Non-releasable, contains proprietary commercial information

Schedule: May 1989 - June 1990

Funding:

Energy R&D Program	$289 593
TDC	$287 873
Total	$577 466

Project Numbers: 7262, 7264, 7336

File Number: 1460-279

Project Officer: Pierre L. Sémery

Typical icebreaker propeller and nozzle arrangement

Modelling of propulsion dynamics

A number of successful full-scale tests of icebreaker propulsion systems have been completed in recent years. Much of this work has been done to provide an adequate experimental basis for the development and validation of numerical modelling techniques for predicting the performance of alternative shafting and bearing arrangements. Such models should not only provide appropriate quantitative information concerning the loads experienced by key system components such as shaft bearings, but should also reproduce the overall qualitative behaviour of the system observed at full scale.

This project involved the development of a software package to access full-scale data and execute numerical models, for the design and evaluation of ice-class shafting and propeller systems. The resulting Shaft Modelling Tool Kit is a suite of programs written for IBM PC/AT compatibles that provides access to key full-scale data from several ice-class vessels; tabular displays of the Canadian Arctic Shipping Pollution Prevention Regulations for powering, shafting and propellers; and analytical modelling of generalized shafting and propeller systems for torsion, thrust, static and dynamic alignment, and torsional, axial, and transverse vibrations. The software is currently being used by designers of ice-class shafting and propeller systems. A useful design tool, it provides the calculated dynamic response of such a system in a matter of minutes. High-quality graphic functions enable the user to evaluate the calculated response of the model by comparing the time history results to measured full-scale data.

Contractor: Fleet Technology Ltd., Calgary, Alberta
Report: TP 9647E, Modelling of ice class shafting and propeller systems, Fleet Technology Ltd., 1988
Schedule: September 1987 - April 1989
Funding: $266 000
Project Number: 6948
File Number: 1460-241-1
Project Officer: Pierre L. Sémery

Typical milling action

Wind and wave climate atlas

In this project researchers are summarizing wind and wave data for the Great Lakes, the Gulf of St. Lawrence, and Canada's East Coast in order to compile a wind and wave atlas. This information is required by regulators and designers when assessing strength requirements of new vessels for operation in Canadian waters and should lead to the development of reliable structural and operational criteria that will more clearly identify and quantify safety margins.

Researchers were required to develop a hindcast data base to fill the extensive gaps in the existing wave climate records for the East Coast and Gulf. A 32-year hindcast for the Great Lakes was contributed by the U.S. Corps of Engineers.

The atlas will be published in three volumes – East Coast of Canada, Gulf of St. Lawrence, and the Great Lakes – and will provide the most comprehensive and up-to-date wave climate data available for these regions. It will be used to develop structural standards that will permit lakers to extend their range beyond the Great Lakes. In addition to Transport Canada, potential users include offshore oil and gas exploration operators, shipowners, and designers.

Contractor: MacLaren Plansearch Ltd., Halifax, Nova Scotia

Report: None to date

Schedule: December 1987 - March 1991

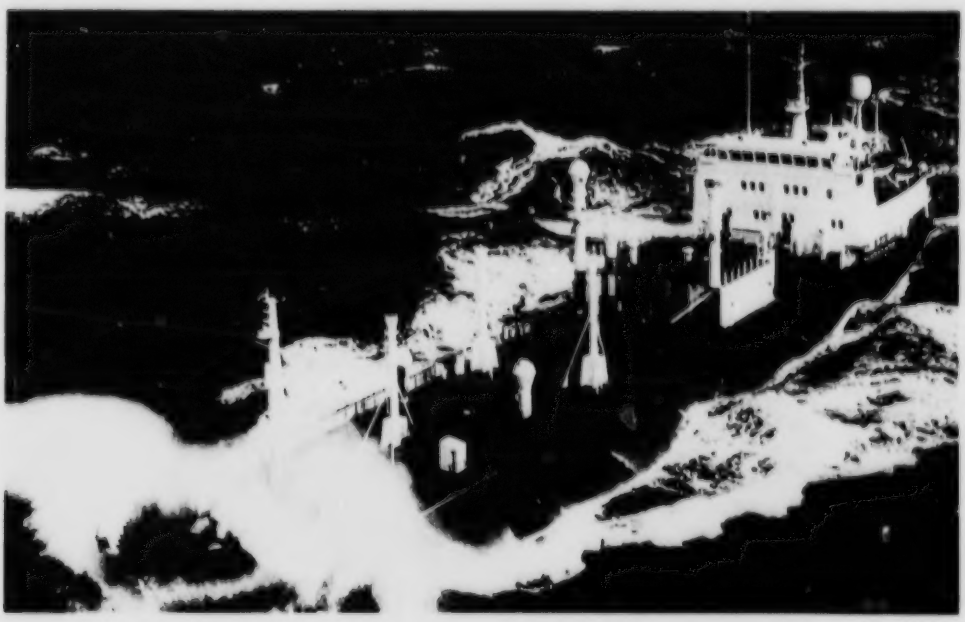
Funding:

TDC	$173 208
Energy R&D Program	$58 612
Canadian Coast Guard	$30 000
Total	$261 820

Project Numbers: 6894, 7419, 7451

File Number: 1460-140-3

Project Officer: Thomas Peirce



Ship manoeuvring standards

In response to a call by the International Maritime Organization to define the manoeuvring performance of existing ships and to regulate the characteristics of new vessels, this study was initiated to develop a systematic method for data collection and reporting. The main objective was to identify and justify a suitable method for predicting the manoeuvring characteristics of a vessel during the preliminary design phase.

Researchers compared the results of their computer analysis to data contained in an international data base and to the results of full-scale ship trials.

A time domain simulation algorithm and two sets of empirical formulae were then selected to predict the manoeuvring characteristics of a vessel during the turning circle, zigzag, spiral, and crash stop manoeuvres. A reasonable level of correlation was achieved between the numerical results and the full-scale trial results, conducted using a laker and a ferry. Although this method cannot be used alone to design vessels to meet specific performance standards, it can be used to check the quality of full-scale, deep-water data for a range of ships.

Contractor: German and Milne Inc., Ottawa, Ontario

Report: TP 9551E, Development of Canadian and international manoeuvring standards, German and Milne Inc., 1989

Schedule: February 1988 - March 1989

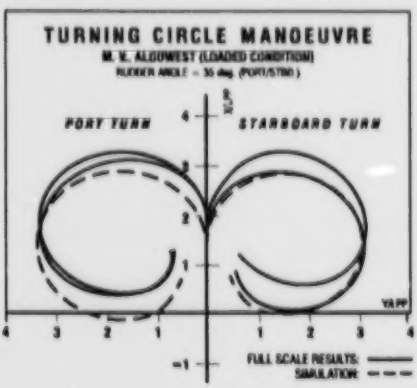
Funding:

Supply and Services Canada	$69 000
TDC	$68 975
Total	$137 975

Project Numbers: 7015, 7017

File Number: 1460-259

Project Officer: Michael A. Stenson



MV Algowest track during turning circle manoeuvre

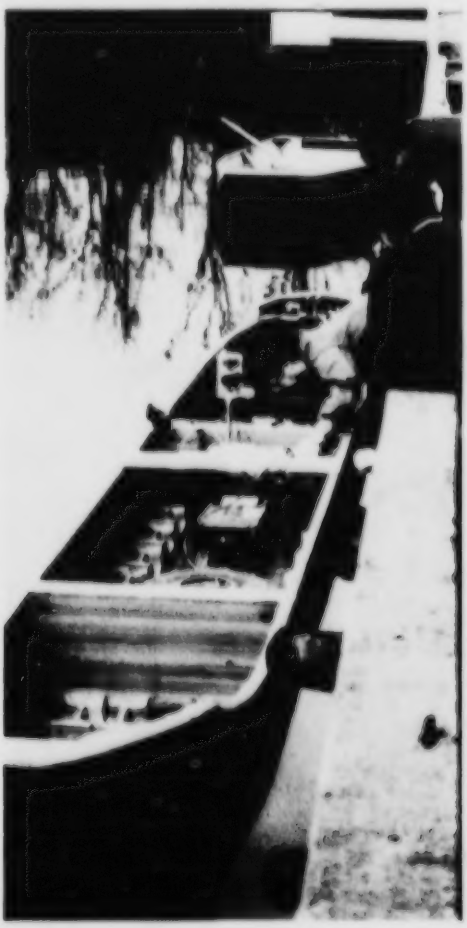
MV Atlantic Freighter

Ship manoeuvring software

A follow-on project to research on ship manoeuvring standards (see p. 9) developed Canadian manoeuvring software and a personal computer-based version of the program. The work aimed to increase the applicability of the software by incorporating new algorithms to analyse vessels fitted with steerable nozzles.

The simulation program was applied to two model-scale vessels that were tested in a manoeuvring basin. The first ship model was fitted with a single rudder/single propeller configuration and its manoeuvring characteristics were predicted by the simulation program as well as being measured by model tests. After comparison of the model-scale and computer results, the computer program was adjusted. The model was then modified by replacing the rudder with a steerable nozzle and retested. The newly developed simulation software was checked against the model-scale results and modified to predict the performance of the altered model. A final set of model tests was carried out on the second model fitted with a steerable nozzle, and its manoeuvring performance was predicted and compared with the measured results. This comparison showed that predicted manoeuvring performance was marginally superior to that measured at model scale.

Contractor: ECS Power Systems Inc., Ottawa, Ontario
Report: None to date
Schedule: October 1988 - November 1990
Funding: $92 983
Project Number: 7375
File Number: 1460-289
Project Officer: Michael A. Stenson



Test preparations of 1:40 scale model at tank side

Drift of common search and rescue objects

One of the most important factors in determining the search area in a search and rescue (SAR) operation is the projected drift of the object. TDC has been involved in a number of projects investigating the drift of common search objects. This project studied leeway movements, i.e., the component of the drift associated with wind acting on the exposed surface of the object.

A four-person Beaufort life raft was tested in various drogued and undrogued configurations, simulating two or four persons aboard. The experiment was done in winds of 0 to 25 knots and in wave heights of 0.1 to 2.1 metres. The leeway was derived by computing the difference between the object's velocity and the current velocity of the upper one metre of the water column at the object. The leeway rates of a drogued and undrogued life raft were found to be considerably less than those specified in the National Search and Rescue Manual currently used by the Canadian Coast Guard. Anticipated leeway experiments will attempt to expand the leeway/drift data to other types of life rafts and to fishing boats of various sizes in higher winds and seas. Once sufficient data has been acquired, it will be incorporated into search planning expert systems and policy manuals, and shared with international publications.

A follow-on project is supporting SAR trials in conjunction with the United States Coast Guard on the Canso Bank off Nova Scotia. Researchers will test the effectiveness of radar transponders and night vision goggles.

Contractor: Nordco Limited, St. John's, Nfld.

Reports: *(From previous research)* TP 10078E, Search and rescue target detection experiment, Canso Bank 1988, Nordco Ltd., 1989

TP 10221E, Search and rescue experiment to derive leeway and drift rates for common search and rescue objects: Notre Dame Bay, Newfoundland, Summer 1989, Nordco Ltd., 1990

Schedule: May 1989 - March 1990

Funding: $249 849

Project Number: 7111

File Number: 1460-220-6

Project Officer: C. Alfred Versailles

Air deployable datum marker buoy system

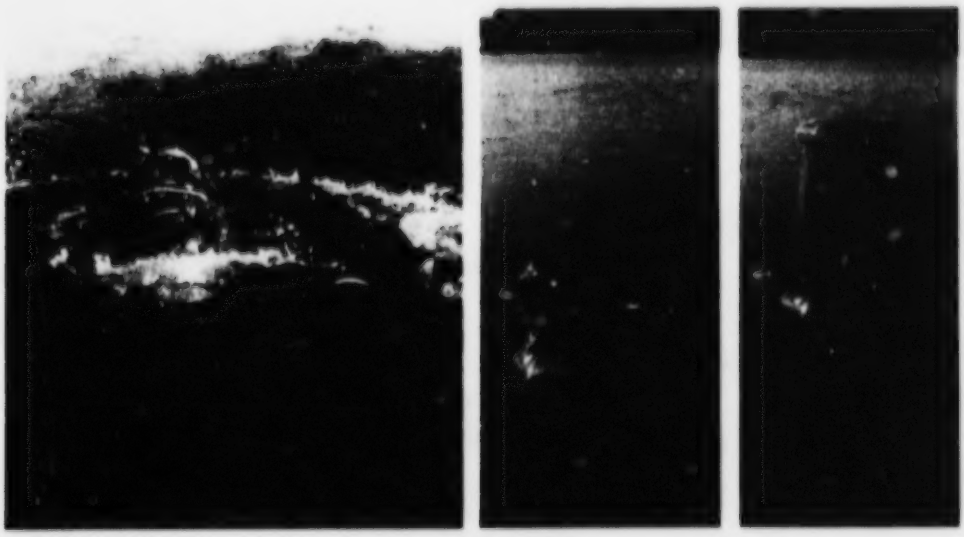
Computer-assisted search planning systems currently in use, such as the Canadian Search and Rescue Planning (CANSARP) program, have numerous inaccuracies that have been traced to a serious underestimation of the actual drift error. Because of the severe limitations of prediction using current physical oceanography, and the large leeway drift factors involved, real-time information is required to determine realistic search areas. A datum marker buoy (DMB), which is being developed in this project to define search areas more accurately, would increase the probability of rescue and decrease the cost of such operations. A Global Positioning System (GPS) using satellite communications technology will be employed in connection with the air deployable device.

Researchers have built five models to test the feasibility of the DMB. These models incorporate dual drift configuration assemblies emulating either the leeway experienced by a maximum drift object, such as an unmanned life raft, or the drift experienced by an object exposed to surface currents, such as a person in the water. The devices include a VHF beacon, solenoid valve controls, switches, a microcontroller and a battery pack. Other subsystems that will be incorporated in later prototype versions are simulated in the models by dummy weights.

Contractor: Seimac Ltd., Dartmouth, Nova Scotia
Report: None to date
Schedule: December 1989 - December 1990
Funding:

Canadian Coast Guard	$197 000
TDC	$52 000
Total	$249 000

Project Numbers: 7435, 7436, 7437
File Number: 1460-294
Project Officer: Louis A. Poulin



Launch, inflation, and operational shots of air deployable DMB

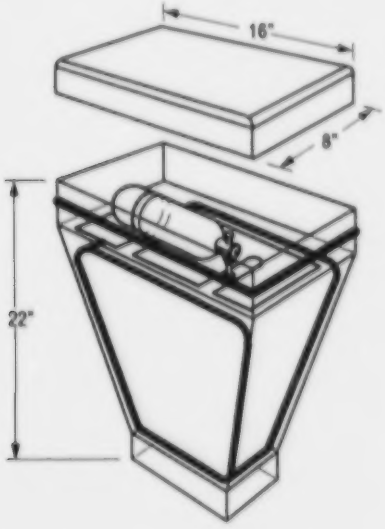
Small vessel life raft

Commercial fishing, an extremely hazardous occupation, employs about 80 000 Canadians. Our short fishing seasons can lead to a disregard for safety, such as fishing in poor weather. Legislation is being introduced to improve safety by requiring small fishing boats to carry sufficient life rafts for the entire crew. A reasonably priced, improved life raft is needed to help meet this requirement.

This project is developing a prototype inflatable life raft to serve the needs of the small vessel fishing industry. It will be simpler to maintain, take less deck space, and cost considerably less than comparable life rafts currently on the market. Technical innovations include:

- a two-part assembly that will allow packaging of the perishable parts of the system separate from those that do not require regular maintenance. This will permit servicing on board by accredited service agents at longer intervals and without major disassembly;
- a weather-proof, airtight valise that will take less space than the typical glass fibre canister requires;
- a unique boarding step incorporated into the life raft hull that will allow a smaller gas bottle for full inflation;
- a retractable canopy for ease of entry and exit;
- use of compressed air instead of CO_2 as the inflation gas;
- use of a composite aluminum/glass fibre reinforced gas bottle refillable at any diving store; and
- a unique drogue-stabilizing system that will also be compatible with existing raft designs.

Contractor: Dunlop-Beaufort Canada Ltd., Richmond, B.C.
Report: None to date
Schedule: November 1989 - November 1990
Funding: $224 018
Project Numbers: 7351, 7352
File Number: 1460-288
Project Officer: Michael A. Stenson



Artist's drawing of two-stage life raft canister

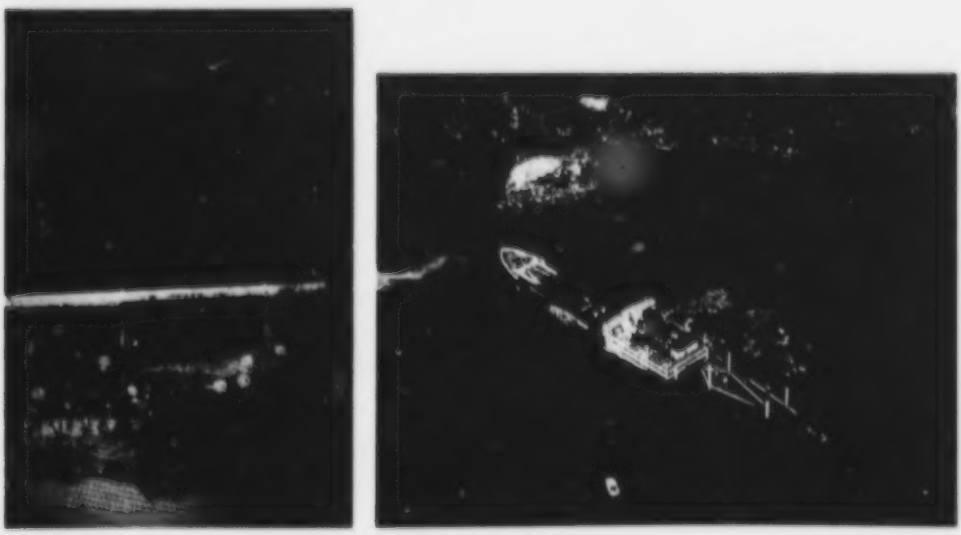
Oil detection and tracking

Protection of the marine environment is of mounting international concern. One of the most important problems is the effect of oil spills. The *Exxon Valdez* incident demonstrated the catastrophic results of spills and the inadequate measures available for spill recovery. Even under favourable weather conditions, oil recovery may be as low as 10 percent of the amount spilled, while the remainder stays in the marine environment and, over time, changes composition. The residue becomes progressively denser, leading to submergence. Submerged oil is subjected to different drift patterns and trajectories from that of surface oil, thus requiring a different procedure to track its movement.

In the first phase of this project researchers are studying the conditions affecting the submergence of oil spills and conducting an extensive search to identify existing or potential technology to detect and track submerged oil spills. The various detection systems will be assessed and the results applied to a pilot project to be used for shipborne experiments in a subsequent phase of the project.

Contractor: Monenco Consultants Ltd., Calgary, Alberta
Report: None to date
Schedule: March 1990 - March 1991
Funding: $35 000
Project Number: 7520
File Number: 1450-161
Project Officer: Thomas Peirce

Underwater view showing the separation of large and small drops of oil



Ship manoeuvrability in ice

The development of Canadian icebreaking technology in the past ten years has demonstrated that the manoeuvrability of icebreakers, particularly in thick ice, can be improved by reamers, spoon-shaped bows, cut-away stems or heeling the ship. Other features, particularly long straight midship bodies, are known to reduce manoeuvrability.

While the performance of several individual ships has been assessed, no concerted effort has been made to collate and analyse the available information and develop a prediction model. By using the breadth of experience now available, a set of criteria could be established for turning and manoeuvring performance in a variety of operations for various ship types. Canada's leading position in icebreaker technology could be maintained by using this unique data base to develop a manoeuvring model as a vital tool in the development of future generations of icebreaking ships for year-round service in the Arctic.

This project developed physical model testing procedures and numerical modelling methods for predicting the turning circle capabilities of three icebreakers representing a typical range of hull forms, dimensions, powers, propellers, and rudder arrangements. The validity of the modelling techniques was evaluated by comparing them with the full-scale turning characteristics of the selected vessels. The results will be used to develop a prediction model for determining the manoeuvring characteristics of icebreakers in level, uniform ice.

Contractor: Fleet Technology Ltd., Kanata, Ontario
Report: None to date
Schedule: March 1989 - March 1991
Funding: $340 441
Project Number: 7243
File Number: 1460-276
Project Officer: Thomas Peirce

Analysis of ice properties and breaking processes

Research and development related to ice resistance depends heavily on effective modelling of the ice sheet in all the complex failure modes involved in icebreaking. However, there is wide concern that model ice does not adequately reflect realistic conditions. This project arose from this concern and the need to establish effective standards to which model ice properties and performance can be related.

In order to determine the full range of significant ice properties, researchers are conducting controlled simulations of realistic ship/ice interactions, using a floating natural ice sheet. A portable rig, designed with an adjustable angled platen to represent an element of a ship's bow plate, will be developed and demonstrated in the field. These demonstrations will parallel tests done at model scale to examine most significant icebreaking processes.

Preliminary tests of ice resistance and breaking properties at model scale have revealed some interesting new concepts of the relative importance of different ice properties in the absorption of energy during the breaking process.

Contractor: Arno Keinonen Arctic Consulting Inc., Calgary, Alberta

Report: None to date

Schedule: February 1990 - April 1991

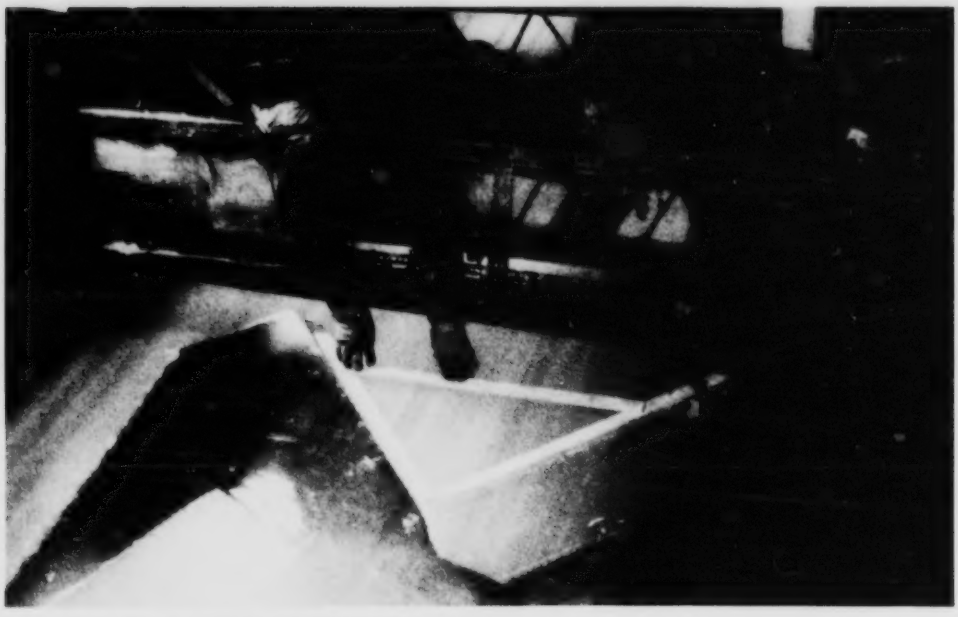
Funding:

TDC	$170 112
Energy R&D Program	$150 000
Total	$320 112

Project Numbers: 7438, 7439

File Number: 1460-297

Project Officer: Ian M. Bayly



Preliminary testing: breaking wedge-shaped cusps of ice

Ice Strength Indexer

Testing ship models in ice basins demands knowledge of the ice's mechanical properties. Their accurate measurement and data on their variation along the basin are of paramount importance. Usually individual samples are cut from the ice sheet prior to and following a model test run. These methods are time consuming and are usually limited to simple tests for flexural strength. Other mechanical properties, such as shear and crushing strength, are assumed to be proportional to the flexural strength.

Supported by TDC and the National Research Council's Institute for Marine Dynamics, Melville Shipping Ltd. has developed a tool that measures the mechanical properties of model ice along the length of the model basin. This Ice Strength Indexer, consisting of ice cutters and flexural, shearing, and crushing plates, is able to accommodate different plate widths, plate angles, and relative positions of the plates and cutters.

The indexer permits measurement of the ice as close to test time as possible, thus avoiding the interpolation or extrapolation to actual test time necessary with conventional manual testing. The wider range of information it provides will significantly increase the accuracy of model ice tank tests in predicting the performance of ice-transiting ships.

Contractor: Melville Shipping Ltd., Ottawa, Ontario

Report: TP 10486E, Ice Strength Indexer - phase III, Melville Shipping Ltd., 1990

Schedule: January 1989 - June 1990

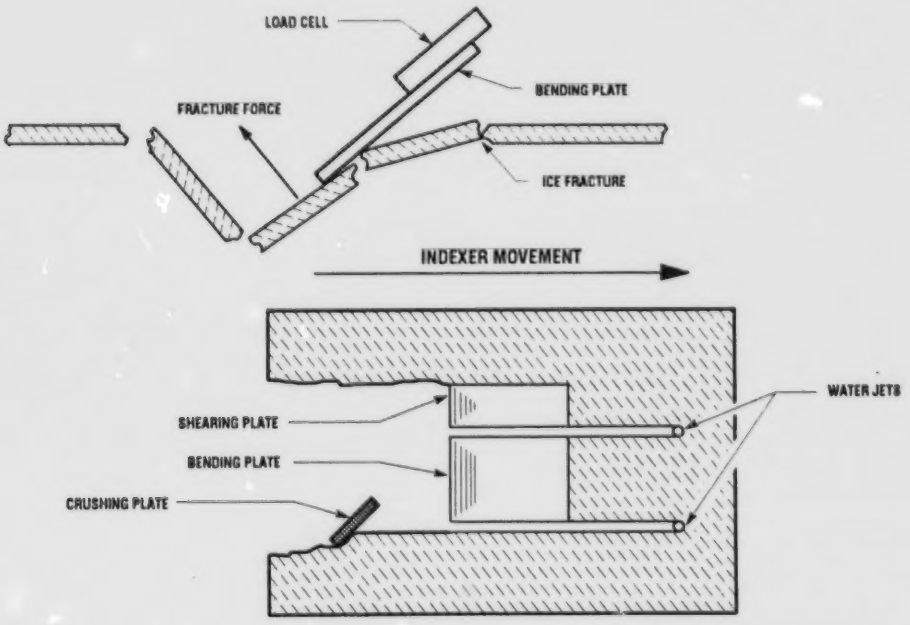
Funding:

TDC	$81 324
National Research Council	$20 000
Total	$101 324

Project Numbers: 7195, 7196

File Number: 1460-226-2

Project Officer: Neil R. Gore



Conceptual arrangement of the Ice Strength Indexer

Propeller/ice interaction forces

The objective of this project was to determine the nature and magnitude of the mechanisms contributing to the loads on propulsion systems in the presence of ice. The accurate prediction of ice loading and the subsequent development of rational criteria for the regulation of machinery protection in icegoing vessels depends on such knowledge. Using a custom-built test apparatus, researchers studied both open and ducted propellers, as well as the influence on ice loading of ice thickness, ice block size, the amount of ice entering the propulsion system, ice strength, propeller pitch and revolutions, and vessel speed.

The ice-induced propulsion loads were separated into two key components: the indirect ice load or ice-induced hydrodynamic load, and the direct contact ice load. Researchers studied the correlation between ship and model propeller ice loading using full-scale trial data for the *Jarvsaar*, an icegoing Finnish trawler equipped with a single CP propeller, tested both with and without a duct. The *Jarvsaar* propulsion system measurements were supported by both underwater video records of propeller and ice interaction and environmental data. A good correlation was established between model predictions and full-scale measurements.

Contractor: Arno Keinonen Arctic Consulting Inc., Calgary, Alberta

Report: TP 10401E, Ice propeller interaction forces, Arno Keinonen Arctic Consulting Inc., 1990

Schedule: February 1989 - May 1990

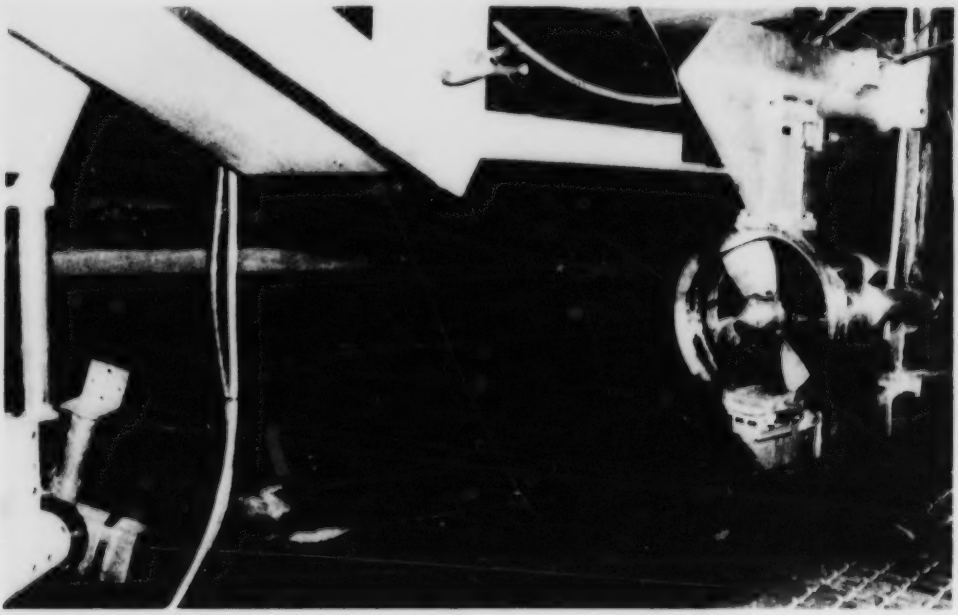
Funding:

TDC	$208 596
Energy R&D Program	$100 000
Total	$308 596

Project Numbers: 7189, 7337

File Number: 1460-265

Project Officer: Pierre L. Sémery



Test apparatus including model propeller

Analytical propeller/ice interaction model

The propeller is the weakest element in the propulsion train of an icebreaker. This project, part of TDC's on-going program in propeller research, sought to quantify the magnitude of impacts of ice on propellers of Arctic-class ships, and their effect on the life of different types of propellers. A propeller/ice interaction program, PRICI, developed during the late 1970s, was updated to include an expanded and improved selection of ice interactions in addition to the original, extensive propeller and ice definitions.

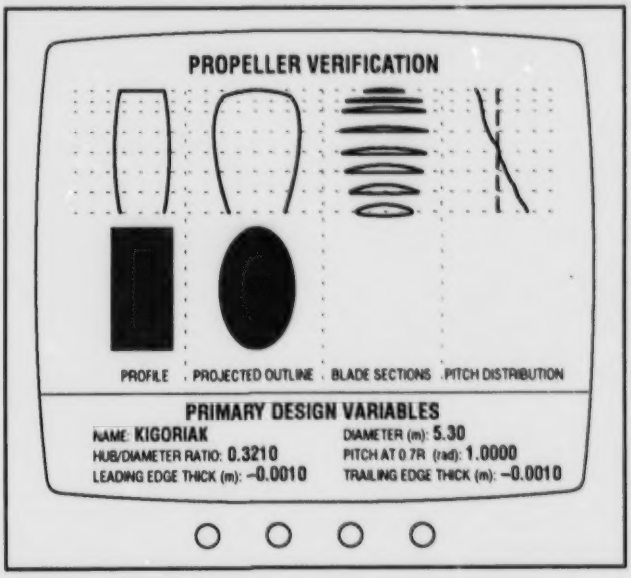
Work included a search of international literature of propeller/ice interaction, a review of current regulatory and classification requirements for ice class propellers and of propeller manufacturers' current design practices, and the calibration of the program against available full-scale and model-scale data.

The original application was studied to ensure that the algorithm structure was compatible with current methodologies. The review considered blade geometry and strength, ice definition, interaction geometry, and ice failure.

A series of sensitivity runs analysed the influence of 17 input variables on the PRICI prediction. These included propeller variables such as diameter, RPM, blade/area ratio, pitch/diameter ratio, and thickness and number of blades. Ice density, crushing strength, shear strength, friction coefficient, and confinement were also examined.

The program was then modified and extended on the basis of this review. The new PRICI is a user-friendly program that can be installed on an IBM-compatible microcomputer.

Contractor: Melville Shipping Ltd., Ottawa, Ontario
Report: TP 10634E, PRICI – An analytical propeller/ice interaction model, Melville Shipping Ltd., 1990
Schedule: December 1988 - October 1990
Funding: $232 010
Project Numbers: 7216, 7218
File Number: 1460-273
Project Officer: Pierre L. Sémery



Sketch of computer screen showing primary design variables for propeller verification

Arctic hull-form optimization

A number of new hull design concepts for Arctic-class vessels have been developed and operationally evaluated over the past decade. However, these concepts have been restricted to small vessels with a specialized local role. Projected estimates of the growing need for transportation of Arctic resources indicate that the future generation of tankers will require large, icebreaking hull forms. Researchers determined that the most efficient way to generate appropriate designs would be to develop two representative hull-forms. The first is designated 20/80, representing 20 percent operations in ice and 80 percent operations in open water, and is the subject of the present phase of the program. The second is designated 80/20, representing the reverse proportions of ice/open water operations appropriate to year-round Arctic service.

The selection of design criteria involved a review of a typical operational environment and of state-of-the-art ship technology. In addition, five of the major Arctic ship designers in Canada provided commentary. The design involved the operational assessment of the tanker transit through the selected environments and the development of a numerical performance evaluation model (TRANSIM) leading to a series of model tests in both ice and open water conditions. Hull forms designed for 110 000 t deadweight tankers were used as the baseline for each operating mission.

Researchers drew a number of conclusions regarding an optimum design and, as a result, work is now directed toward improving manoeuvrability and operating performance of the 20/80 hull in non-level first-year ice.

Contractor: Canarctic Shipping Company Ltd., Ottawa, Ontario

Report: Non-releasable, contains proprietary commercial information

Schedule: August 1988 - March 1991

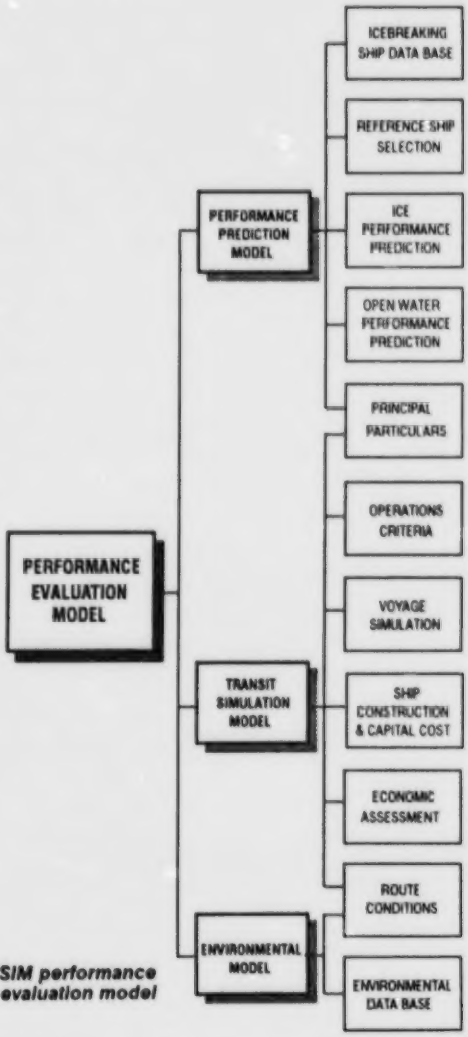
Funding:

Energy R&D Program	$498 145
TDC	$236 376
Total	$734 521

Project Numbers: 7114, 7115, 7394, 7487, 7488

File Number: 1460-261

Project Officer: Thomas Peirce



TRANSIM performance evaluation model

Influence of beam variation on the resistance of icebreaking ships

Icebreaking resistance has traditionally been determined by subjecting each vessel to its own unique model investigations. The resulting value of the resistance in each case is not generally amenable to separation into the contribution to total resistance made by each dimension of the hull form. For a designer, accurate knowledge of the components of resistance, and particularly of length and beam effects, is vitally important to the development of optimal, economically feasible icebreaker designs.

In this second phase of work aimed at developing a quantitative understanding of the influence of various hull elements on icebreaking resistance, a series of model tests, based on the MV *Arctic*, was conducted using a range of parallel midbody lengths and breadths. Results presented data as resistance versus length/breadth (L/B) ratio normalized to a constant ship displacement. It was found that, contrary to traditional belief, resistance was only moderately affected by L/B ratio but was sensitive to bow geometry.

A follow-on phase is designed to integrate these results with test results from other programs to obtain a sufficient range of parameters to confirm the relationships posited. If confirmed, this work would open up new opportunities in hull-form design, particularly for the optimization of resistance and manoeuvrability of icebreakers.

Contractor: Melville Shipping Ltd., Ottawa, Ontario

Reports: *(From earlier research)* TP 9242E, Effect of parallel midbody on the resistance of ships in level ice, Melville Shipping Ltd., 1988

TP 10161E, Icebreaking midbody resistance – phase II: beam variation, Melville Shipping Ltd., 1990

Schedule: January 1989 - May 1990

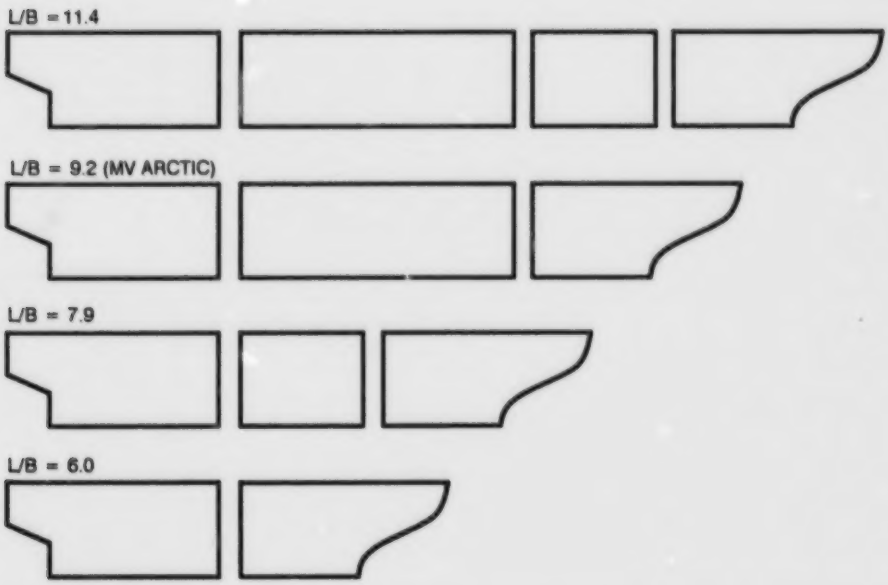
Funding:

TDC	$176 150
National Research Council	$30 000
Total	$206 150

Project Numbers: 7203, 7204, 7205

File Number: 1460-270

Project Officer: Thomas Peirce



Sketch of model segments, based on the MV Arctic, used to assess the influence of parallel midbody on ship performance in level ice

Verification of Carter model bow

This project conducted a series of model tests to ascertain the ice and open water performance of a new concept of icebreaking bow, known as the Carter Bow Form, generated by the Carter mathematical prediction model. The bow's efficiency was compared to that of the original R-Class bow form. Tests were conducted on two 1:20 scale models in both the ice tank and the towing tank at the Institute for Marine Dynamics in St. John's, Newfoundland.

Results of these tests indicate that the Carter bow could provide more efficient icebreaking without penalty in ice-clearing ability or open water resistance. The new form achieved a 25 percent decrease in level ice resistance. Researchers believe that even greater improvement may be achieved and have therefore recommended further testing.

Contractor: Donald Carter and Associates, Ste-Foy, Quebec

Report: TP 10617E, Results of comparative model tests with conceptual hull form and the original R-class icebreaker, Donald Carter and Associates, 1990

Schedule: March 1990 - October 1990

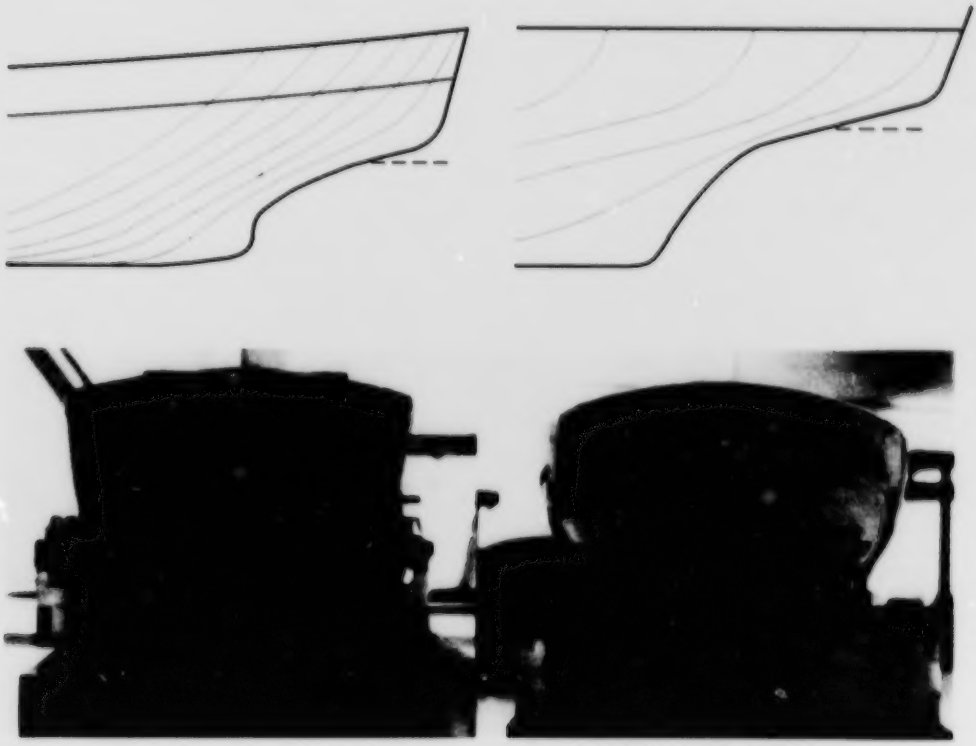
Funding:

TDC	$106 885
Canadian Coast Guard	$75 000
Total	$181 885

Project Numbers: 7497, 7498

File Number: 1460-177-4

Project Officer: Thomas Peirce



Profiles and front views of the R-class (left) and Carter bow forms

SA-15 hull-form resistance

SA-15 icebreakers are 15 000 t deadweight cargo vessels built by Wartsila and Valmet shipyards in Finland for year-round operation in the Soviet Arctic. In 1989 an opportunity arose to test this hull form in Canada and develop a new form based on the Melville bow successfully fitted to the MV *Arctic*.

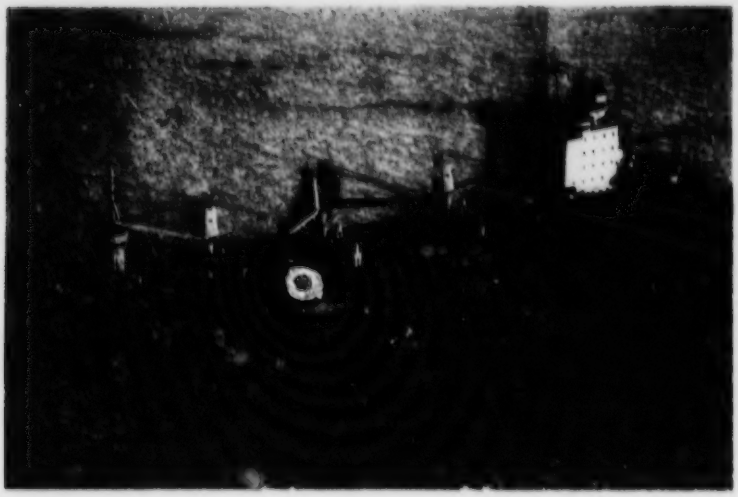
The project was designed to complement and verify the results obtained from the icebreaker midbody resistance program (see page 21) as part of a long-term effort to increase understanding of the influence of various hull-form elements on ice resistance.

Researchers constructed a 1:28 scale model section of an SA-15 cargo icebreaker with interchangeable bows – the existing bow and a new bow based on the MV *Arctic* design. The resultant models, representing a vessel of about 7.0 length/breadth (L/B) ratio, were resistance-tested at the Institute for Marine Dynamics to determine the effects of each bow form.

Results confirmed that the level-ice performance of the SA-15 icebreaker can be improved by more than 35 percent by fitting a Melville bow form, without adversely affecting its performance in calm water.

The Canadian Marine Transportation Group, a consortium of private marine interests, and the USSR's Ministry of Shipping are now discussing the possibility of the conversion and full-scale trials of one SA-15 vessel.

Contractor: CSE Marine Service Inc., St. Catharines, Ontario
Report: Non-releasable, contains proprietary commercial information
Schedule: February 1989 - February 1990
Funding: $151 089
Project Number: 7254
File Number: 1460-277
Project Officer: Thomas Peirce



A typical SA-15 icebreaker

Icebreaker design synthesis

The first phase of this project assembled data on the design and performance of new commercial icebreakers in the Beaufort Sea. Quantitative relationships were derived for turning radius in ice, open water resistance, ice transit, and effectiveness of bubbler or deluge auxiliaries from an analysis of full-scale tests and interviews with the ships' captains. Researchers also studied the performance of propeller nozzles and concluded that substantial gains in ahead performance are offset by significant blockage losses, particularly astern in a broken channel.

The current phase is adding to the data and extending and applying the models and methodology developed in the earlier work. These quantitative relationships are an important design tool, facilitating the achievement of a hull form, appendages, and auxiliaries that are well matched to operational requirements. The techniques will be adapted and extended to incorporate design features of icebreakers with traditional roles. In addition, performance estimation models for key design features will be further developed.

This knowledge of the effects of design arrangements on performance will also contribute to the formulation of regulations stipulating the minimum capabilities required for safe operation in Arctic waters.

Contractor: Arno Keinonen Arctic Consulting Inc., Calgary, Alberta
Report: Non-releasable, contains proprietary commercial information
Schedule: December 1989 - June 1991
Funding: $138 839
Project Number: 7430
File Number: 1460-243-2
Project Officer: Ian M. Bayly

The Canadian Coast Guard's new type-1200 heavy icebreaker, CCGS Henry Larsen

Cathodic protection anode

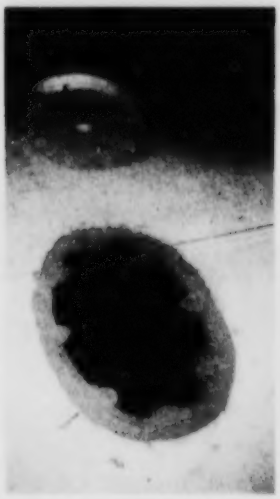
Corrosion of the hulls of ice-going vessels is a serious problem. By reducing the high corrosion rates currently found on the exposed shell plating on the hulls of icebreakers, cathodic protection technology can help to alleviate a major maintenance problem. Reducing the frequency of dockings for refurbishment of hull coatings has important economic benefits for shipowners. While it has been shown that impressed-current cathodic protection systems can minimize this problem, many existing anode designs, when used on icebreakers, are prone to damage and failure due to ice impacts.

This project developed and tested a new type of impressed-current cathodic protection anode that is expected to last approximately ten years in service aboard icebreaking ships, as opposed to the one- to two-year life expectancy of other anodes. Titanium anode plates were coated with a highly durable, yet electronically porous, mixed oxide coating. They were then mounted flush with the outer hull surface and joined to it with special non-conducting bolts. The flush mounting eliminated lips and edges that could be abraded by contact with ice. The anodes were connected to the existing impressed-current systems and tested on three icebreakers – the MVs *Kigoriak*, *Kalvik*, and *Ikaluk* – operating in the Beaufort Sea. This sea has proved to be an excellent testing ground for corrosion protection systems. Ship corrosion is four to five times greater in these Arctic waters than it is anywhere else, because of the high concentrations of oxygen in the water and the rapid breakdown of hull paint coatings in this environment.

After one year of operation, an underwater survey conducted on the MV *Kalvik* found that all anodes were intact and operating efficiently.

Contractor: David Peters Services Inc., Duncan, B.C.
Report: *(Draft)*, Design and testing of impressed-current cathodic protection anodes for use on icebreaker hulls, David Peters Services Inc., 1990
Schedule: April 1989 - August 1990
Funding: $52 000
Project Number: 7293
File Number: 1460-285
Project Officer: Michael A. Stenson

Damaged recessed anode



Recess prepared to receive anode shown above newly installed coated anode

Completed installation of two anodes

Evaluation of strakes

Following work by Kristi Maritime of Pointe Claire, Quebec, to evaluate the reduction of icebreaking resistance effected by strakes attached to the ship's bow, this project determined the effect that the strakes had on the icebreaking performance of the CCGS *Sir Wilfrid Laurier*. (Strakes are skegs or metal plates attached to the ship's hull at an angle along the ice-contact line. They promote flexural rupture of the ice, thus reducing icebreaking resistance and alleviating ice pressure on the ship's side.) Full-scale trials were conducted in level unbroken ice on the Saguenay River in the winter of 1990.

Torque, rpm, and thrust for both shaftlines were measured and recorded, as well as ship speed. A series of tests were conducted in relatively constant ice thickness, at a number of speeds and power levels. Two continuous turning tests evaluated the turning performance of the vessel.

While no quantitative conclusions on the effectiveness of the bow strakes in improving icebreaking resistance could be made, analysis of the videotaped tests indicated that positioning the strakes further forward and lower than the present location would be more effective, since the bow section of the vessel rises approximately 0.3-0.5 m while level icebreaking ahead in 0.8-0.95 m of ice, and this trim change affects the optimum position and inclination of the strakes. Additional tests to provide quantitative data to confirm these findings are being considered.

Contractor: Fleet Technology Ltd., Calgary, Alberta

Reports: *(From earlier research)* TP 10553E, Design and application of strakes on a Canadian Coast Guard ship, Kristi Maritime, 1990

TP 10554E, Verification through field measurements of the extent of reduction in icebreaking resistance for icebreaking strakes, Fleet Technology Ltd., 1990

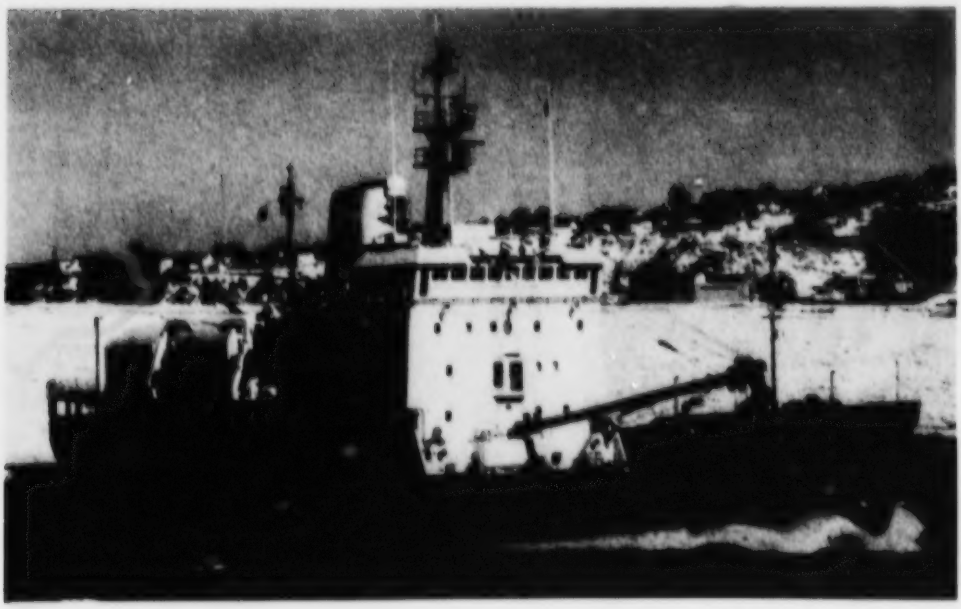
Schedule: January 1990 - August 1990

Funding: $40 038

Project Numbers: 7477, 7478

File Number: 1460-239-3

Project Officers:
Jacques E. Laframboise, Michael A. Stenson



CCGS Sir Wilfrid Laurier

Ice navigation station on the MV Arctic

Over the past ten years, TDC has supported work culminating in the world's first commercial ice navigation system, now installed on board the MV *Arctic*.

This Shipboard Integrated Navigation Support System (SINSS) includes satellite links providing a strategic overview of weather and ice conditions, synthetic aperture radar imagery developed in Canada specifically for ice mapping, and specialized ice radars and other technologies (such as sonar) for close detection of ice hazards. The system helps detect hazards in ice-infested open waters and hazards camouflaged in first-year ice or hidden by snow cover.

Development of the SINSS technology has resulted in an operational ice navigation system and important spin-offs in ice navigation technology that are being applied on board Canadian Coast Guard vessels. The technology also has potential for industrial spin-offs through joint ventures or sales to other countries involved with operations in Arctic and Antarctic waters.

Complete development of this technology will take at least another five years. In recent follow-on work, the functional specifications for an advanced, second-generation ice navigation system have been identified.

Contractor: Canarctic Shipping Co. Ltd., Ottawa, Ontario

Reports: TP 10105E, Arctic marine radar development, phase I, Canarctic Shipping Co. Ltd., 1990

TP 10156E, Radar data gathering on MV *Arctic*, Canarctic Shipping Co. Ltd., 1990

TP 10565E, Functional specifications for second-generation ice navigation system, Canarctic Shipping Co. Ltd., 1990

Schedule: October 1988 - January 1990

Funding:

TDC	$52 480
Energy R&D Program	$18 584
Total	$71 064

Project Numbers: 7184, 7448

File Number: 1460-146-8

Project Officer: Maurice Audette

***SINSS console installed on the MV* Arctic**

Development of radar-assisted precise navigation (NAVFIX/RANAV)

For a number of years TDC has been involved in the development of a reliable, cost effective, all-weather system that can provide accurate vessel positioning in inland and coastal waterways, particularly in areas where the shoreline does not offer the good radar reflection normally needed for precision.

This research resulted in the development and demonstration of a NAVFIX prototype, a precision navigation display system for coastal and inland vessel navigation. NAVFIX combines a French-developed radar positioning system with two uniquely Canadian technologies: the electronic chart, Precision Integrated Navigation System (PINS) developed by Offshore Systems Ltd., and McMaster University's polarimetric radar positioning system. It provides positional accuracy approaching that of existing microwave shore-based systems by using precision shipboard radar and a chain of shore-based passive retro-reflectors, thus eliminating the need for troublesome active shore-based transponders.

The current project is further developing the radar-assisted precise navigation (RANAV) system. Researchers will address issues raised during the previous development, including the design of improved passive depolarizing targets, the definition of more effective site evaluation processes, the design of an alternative radar to signal processor interface, and the development of improved software for remote buoy positioning and target-clutter discrimination.

A full-scale demonstration aboard a Canadian Coast Guard ship in the St. Lawrence River is under consideration.

Contractor: Offshore Systems Ltd., North Vancouver, B.C.

Report: *(From previous work)* TP 9728E, Precise radar integrated navigation system (NAVFIX) for coastal and inshore navigation, Offshore Systems Ltd., 1988

Schedule: May 1990 - January 1991

Funding:

TDC	$258 097
Energy R&D Program	$158 000
Total	$416 097

Project Numbers: 7457, 7682

File Number: 1460-249-2

Project Officers: Maurice Audette, Mel Walker

The use of trihedral constellations in areas with poor natural radar definition allows NAVFIX/RANAV to locate a ship's position.

SINADS II

The increasing quantity and complexity of navigational information available from electronic navigational aids has created the need for the management, integration, and display of this data on an integrated bridge display console. Previous work by Offshore Systems Ltd., supported by TDC, developed an advanced prototype of the Shipboard Integrated Navigation and Display System (SINADS) concept. SINADS can superimpose radar images on pre-stored digital electronic charts to graphically represent a ship's location. It offers important benefits to the Canadian Coast Guard and users of the St. Lawrence Seaway and other narrow channels, since it allows safer and more accurate navigation in confined waters by providing vital information on a single screen, thus freeing the operator from the need to scan several screens in turn or to frequently consult charts.

This project is further developing the system to the production prototype level, following evaluation aboard the CCGS *Nicolet* during the fall of 1988. Refinements in SINADS II include reduced interactive response time and expanded capability to accept LORAN-C and GPS input. The human-machine interface has been greatly improved by a re-designed console, the introduction of a trackball to manipulate the cursor, and an electronic touch screen.

Contractor: Offshore Systems Ltd., North Vancouver, B.C.

Report: *(From previous research)* TP 9696E, Development and evaluation of a shipboard integrated navigation and display system, Offshore Systems Ltd., 1988

Schedule: June 1989 - December 1990

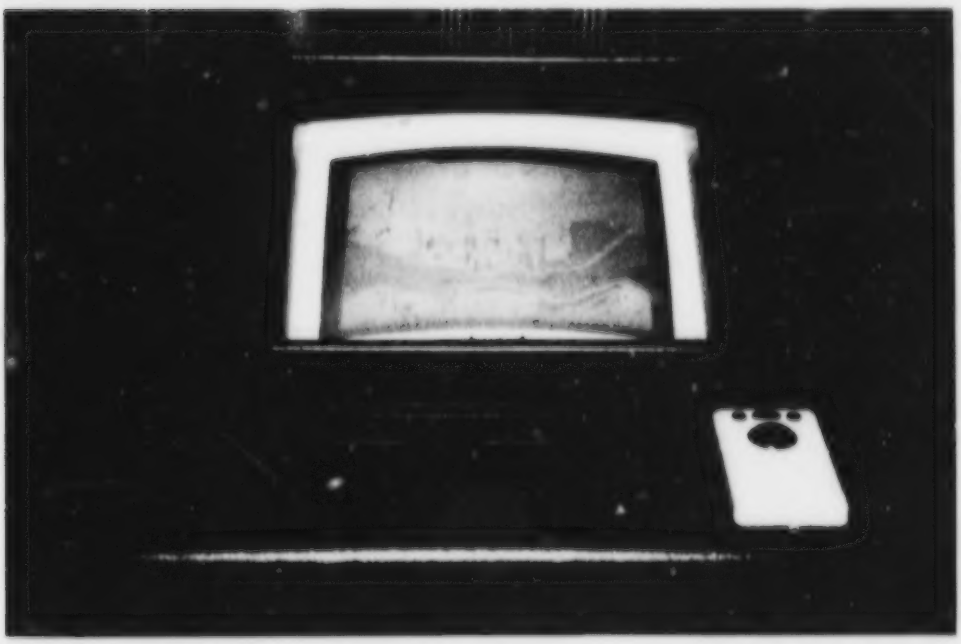
Funding:

Energy, R&D Program	$226 482
TDC	$65 618
Total	$292 100

Project Numbers: 7279, 7280

File Number: 1460-245-3

Project Officer: James D. Reid



SINADS II operator's display

Airborne ice thickness sensor

TDC has supported the development of remote ice thickness measurement technology since 1980. In recent work conducted by Canpolar Inc. of Toronto, researchers compared three experimental, all-weather, airborne systems in Arctic field trials. Electro-Magnetic Sensors (EMS), already in use for geological surveys, were found to profile a variety of ice types and thicknesses most effectively.

In the current project, the experimental sensor is being redesigned to improve its ability to measure ice thickness. Operations from a Canadian Coast Guard icebreaker helicopter impose a number of design and safety requirements that were not considered in the original sensor design. The current size of the towed "bird" that carries the sensor was dictated by the very low frequency needed for detection of geological features. The optimum frequency of operation is significantly higher for ice thickness measurement, allowing for a reduction in its size. Winching will be provided to facilitate securing the "bird" between the helicopter skids, especially for take-off and landing. Special displays incorporated into the system will ensure that pilots can maintain safe operations when the sensor is in operation, and provide an immediate reading of the ice thickness being measured.

Contractor: Aerodat Ltd., Mississauga, Ontario
Report: None to date
Schedule: June 1989 - June 1991
Funding: $549 600
Project Numbers: 7249, 7250, 7537
File Number: 1460-126-11
Project Officer: Maurice Audette

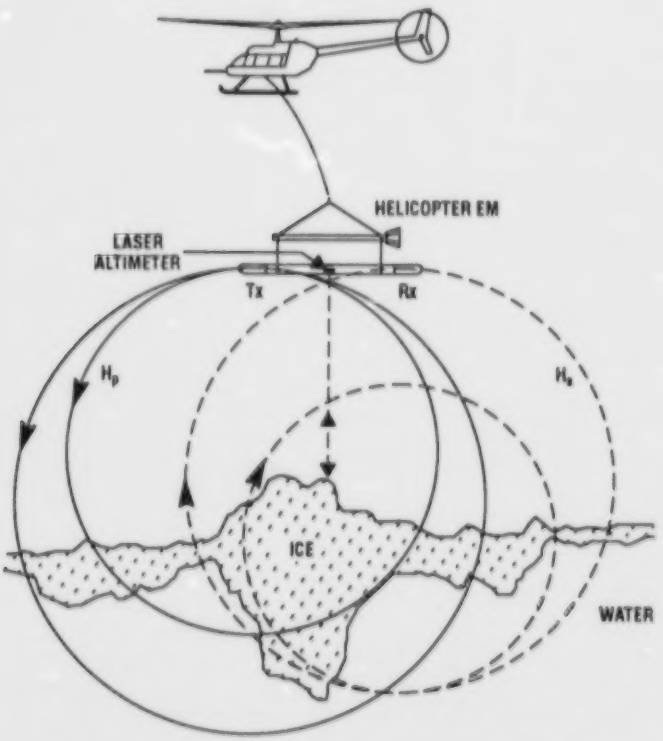


Illustration of the helicopter-borne electromagnetic sensing system. The transmit coil creates a primary magnetic field, H_p, that sets up eddy currents in a conductive medium such as ice. The resulting secondary magnetic field, H_s, is detected by the receive coil.

Ship vibration analysis

The Canadian Coast Guard's current approach to vessel maintenance consists of a scheduled program that requires ship systems to be dismantled and rebuilt at fixed intervals regardless of their condition, as well as a predictive maintenance program. By detecting problems before they become serious, predictive maintenance, including vibration monitoring, spectroscopic and ferrographic oil analysis, and event recording, enables machinery to be run to maximum life with reduced maintenance. A shift to a program based wholly on predictive maintenance would therefore be more economical and less destructive to equipment. Furthermore, ship engineers would not have to remain with one vessel for the duration of a complete equipment evaluation, since the expert system would permit consistent decision-making by maintenance personnel.

Vibration analysis, one of the best established predictive maintenance techniques, is currently conducted on Coast Guard vessels through the use of hand-held analysers. Vibration signatures of equipment are acquired and analysed by experienced engineers, to determine whether a particular machine is functioning properly. However, these experts are not always available to interpret data and much of the data is vessel-specific.

To overcome these problems, researchers have developed a PC-based prototype expert system that can accept vibration signatures, analyse and compare them with stored data, and forward recommendations for preventive maintenance scheduling, fault diagnostics, and quality assurance. The software is currently on trial aboard the CCGS *Sir William Alexander*.

Contractor: Design Maintenance Systems Inc., North Vancouver, B.C.
Report: None to date
Schedule: June 1989 - September 1990
Funding: $257 256
Project Numbers: 7199, 7219
File Number: 1460-266
Project Officer: James D. Reid

CCGS Sir William Alexander

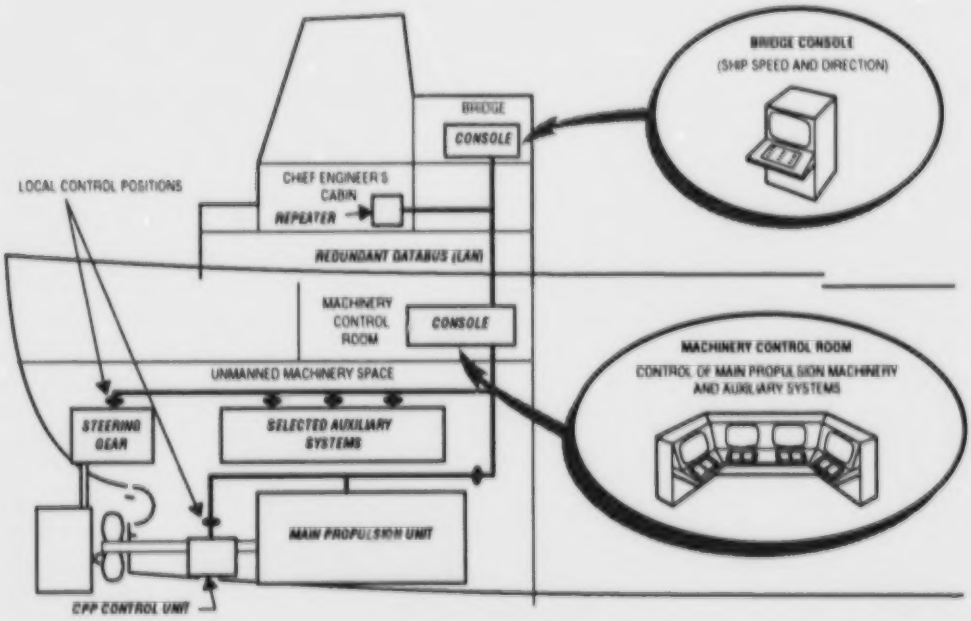
Ship control systems specifications

Machinery control systems, vital to modern ships, are extremely complex and expensive. The Canadian Coast Guard and the Department of National Defence are seeking more efficient and reliable, less labour-intensive, and safer machinery plants. The tendency to buy "off the shelf" equipment systems has been called into question because the long duration for construction of new ships can make these systems outdated before they are put to use.

This project is designed to develop comprehensive, easily updated baseline specifications for hardware, software, documentation, and acceptability criteria for ship machinery control systems. In addition, it will develop a detailed understanding of the R&D required in advanced machinery control theory and practice to keep the specifications up-to-date.

Researchers are considering the human-machine interface; the establishment of a specification format and an interface signal list; standards for the development of a monitoring and control system; and software and hardware standards. Maintenance policy and procedures will also be developed. Several baseline specifications have already been completed.

Contractor: Gastops Ltd., Gloucester, Ontario
Report: None to date
Schedule: November 1989 - March 1991
Funding: $245 155
Project Numbers: 7331, 7332
File Number: 1460-287
Project Officer: Michael A. Stenson



Specifications for digital machinery monitoring and control systems

Comparison of fibre-optic and conventional transmissions

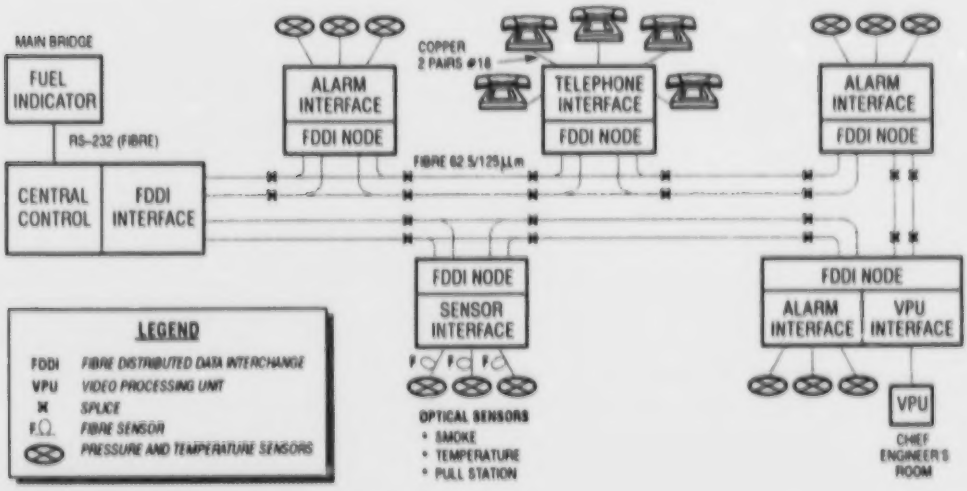
The inherent characteristics of fibre-optic technology – high bandwidth, light weight, small cross-sectional size, and immunity to electromagnetic interference – make it attractive for marine applications, particularly as a solution to some of the transmission problems caused by radio interference and as an important element in the integration and automation of various shipboard systems.

This study evaluated the technical and economical viability of using fibre-optic technology in place of existing copper-based cabling techniques for a number of specific systems on board Canadian Coast Guard vessels. In all cases the fibre-optic alternative was found to be more expensive than the copper-based system, by an average ratio of 14 to 1. The fibre-optic systems, however, were designed with costly custom-made interfaces, since this equipment was not commercially available.

The concept of system integration was also evaluated. Four systems – public address, PBX, fire detection, and alarm monitoring and control – were found suitable for integration with a single fibre-optic Local Area Network (LAN) on board. Such integration was found to promise significant cost savings.

Researchers concluded that existing installations are unlikely to be replaced by fibre-optic technology until manufacturers introduce systems already incorporating this technology. The Canadian Coast Guard is now studying the project findings.

Contractor: DTI Telecom Inc., Montreal, Quebec
Report: TP 10452E, Comparative study on the use of fibre optics and conventional cabling systems on board CCG vessels, DTI Telecom Inc., 1990
Schedule: July 1989 - December 1989
Funding: $40 000
Project Number: 7210
File Number: 1460-272
Project Officer: James D. Reid



Integrated network with alarm monitoring, PBX, and fire detection systems

Canadian Coast Guard watch scheduling

The relationship between work schedules and the health and performance of workers has been documented in a number of scientific studies. However, the schedules in effect on Canadian Coast Guard ships – six-hour watches and daily, round-the-clock 12-hour schedules – have not been the subject of much research. This project collected and analysed systematic data on the physiological and psychological repercussions of current work schedules on the crew of the CCGS *Simon Fraser*. Researchers made recommendations designed to increase the efficiency of personnel and suggested a number of changes applicable to all Coast Guard ships.

The schedules under study had distinct characteristics: daily 12-hour schedules within a cycle of 28 consecutive working days were followed by an equal period of rest. Work at sea has its own particular features. Round-the-clock operation engenders specific problems because the abnormal working hours disturb the body's natural activity-rest rhythm, which is adjusted to the alternation between day and night. Schedules for shift work at sea are different from those in other transportation modes because of the nature of the tasks and the continuous availability of crew. If certain surveillance activities are undertaken by one group for too long, the safety of ship and crew can be jeopardized.

The project demonstrated that daily 12-hour schedules were just as disturbing to crew as six-hour schedules with a night watch. Those working days on six-hour watches felt the least disturbance.

Researchers recommended several alternative schedules. The most advantageous appears to be a rapid rotation system using a 12-hour schedule with three work crews employed during a 28-day work cycle.

Contractor: GIROSST, Laval University, Ste-Foy, Quebec

Report: TP 10048E, Work scheduling on Canadian Coast Guard ships: physiological and psychological impacts, GIROSST, 1989

Schedule: February 1989 - April 1990

Funding: $130 051

Project Numbers: 7234, 7235

File Number: 1460-275

Project Officer: Jacques E. Laframboise

Researchers studied the effects of various work schedules on the performance of CCG crews.

AIR TRANSPORTATION

AIR TRANSPORTATION

TDC's air technology program supports Transport Canada's role in air navigation, air traffic control, airport operations and flight regulations, while stimulating cooperative R&D activities with industry. Many of its projects stem from implementation of the Canadian Airspace Systems Plan, the Canadian Automated Air Traffic System project, and the Microwave Landing System Program. TDC's work in this area is conducted in collaboration with various divisions of the Aviation Group and the Airports Group.

Flight Safety

Transport Canada has a direct role in ensuring the safety of the Canadian air transportation system. Research and development in the area of flight safety is closely related to the department's regulatory and certification responsibilities. With the increasing use of composites and other advanced materials, regulation of aircraft structural integrity and safety is becoming more difficult. TDC is supporting work to evaluate new materials and to develop appropriate verification and inspection technology. TDC projects also address the prevention and investigation of accidents as well as the question of survival. One important initiative is the improvement of Emergency Locator Transmitters (ELTs) – the most effective devices for determining the location of downed aircraft. Projects concerned with accident prevention include the investigation of new de-icing chemicals and their effects on commuter aircraft, and sensors for detecting ice accumulation on aircraft surfaces. Aircraft performance on wet runways is also being studied to assess the merits of various procedures in reducing risks.

The greatest number of aircraft accidents occur with small private aircraft and small commercial aircraft flying in remote areas. A TDC project that studied the use of shoulder harnesses by crew in smaller aircraft indicated that their mandatory use could reduce injuries and fatalities.

Air Navigation Services

Transport Canada is responsible for air navigation services for the national airspace and for some international territory over the Atlantic. These services affect not only the safety of Canadian aviation, but also the capacity and the efficiency of air operations in these areas. TDC is supporting projects to study design aids, navigation and communications aids, workstations and human-machine interfaces, and future air navigation systems.

Emerging technologies offer new opportunities to improve the design and engineering of facilities and aviation procedures, through the use of computer tools combined with advanced graphic displays and expert systems. A prototype of an airspace design expert system has been developed in work supported by TDC.

As part of the Canadian Airspace Systems Plan to modernize air traffic services, weather reporting, and air navigation systems, Transport Canada plans to have up to 140 Microwave Landing Systems (MLS) installed at Canadian airports. MLS is technically superior to the current instrument landing system, and offers guidance procedures not previously possible, such as curved or segmented guided approaches. TDC is supporting research to expand the now limited measurement and engineering instrumentation for MLS applications. One project is investigating the use of monolithic microwave integrated circuits in MLS antennas. In another, researchers are developing an independent hardware monitor as a backup to the MLS software. Distance measurement equipment interrogators for engineering instrumentation are the subject of a conceptual study aimed at eventual implementation.

AIR TRANSPORTATION

To cope with the growing demands on their time and attention, air navigation personnel – air traffic controllers, operators, maintenance technicians, design engineers, and managers – require well-designed workstations and efficient automated systems. TDC projects are focussing on ergonomic studies of workstations, computer display technologies and methods, intelligence advisory systems for air traffic conflict resolution, and alternative data entry methods, such as voice recognition systems.

The provision of meteorological information is an important responsibility of the air navigation services. Work is under way on the development of an expert system for airport weather forecasting.

Airborne computing and satellite terminals are expected to provide innovative means of air navigation. A series of studies on related topics has been completed in support of the Future Air Navigation System working group of the International Civil Aviation Organization.

Airport Security

Airport security research is directed toward development of new detection and identification technologies for portals, carry-on luggage screening, and checked baggage. Advanced technology is being developed to improve the effectiveness and reduce the cost of inspecting baggage. Projects to study an advisory system for X-ray operators screening on-board luggage, ion mass-spectrometry "sniffing" of explosives, and vapour laser preselectors to be used with chemical sniffers indicate that significant improvements are possible.

Airport Operations

The airport operations R&D program focusses on planning, environmental issues, and runway design. Capacity problems at Vancouver International Airport presented an excellent test case for the development of an airside planning model.

Environmental concerns have led to a study of sealants to prevent damage to water sources in the area of Halifax International Airport, and to an investigation of strategies for the management of airport noise.

Runway design, operation, and maintenance represent an important portion of the resources allocated to construction and operation of airports in Canada. Researchers are studying landing patterns of small aircraft to determine whether runway widths, particularly in remote airfields, could be reduced, with a view to more economical construction.

Advanced Concepts

Research into advanced concepts and technologies in aviation includes work on computer modelling of nacelles, and an investigation of how the use of tilt rotor aircraft may affect airports in the future. Both these projects offer opportunities for energy conservation.

Certification of composite aircraft structures

Major advances in airframe construction could be achieved by making primary aircraft structures from composite materials. The lighter airframe afforded by the use of such materials would increase energy efficiency and reduce fuel consumption. However, because the performance of conventional metal construction materials is well documented, while that of composites under operating conditions is virtually unknown, to date only secondary structures made from composite materials have been acceptable for certification.

This project is investigating advanced composite components for use in such primary aircraft structures as wings. Researchers are conducting a simulated certification program for a wing panel, including materials testing and theoretical analysis to determine principles applicable to the certification of all composite materials.

Test results will provide the information required to establish criteria for acceptance of designs, modifications, and repair of primary components made from these materials.

Contractors: Bombardier Inc. and Canadair Ltd., Montreal, Quebec

Report: None to date

Schedule: September 1989 – July 1991

Funding:

Energy R&D Program	$240 000
Canadair	$221 808
TDC	$203 684
Total	$665 492

Project Numbers: 7148, 7149

File Number: 1455-205

Project Officer: C. Alfred Versailles

The Canadair Challenger already uses composite materials in a number of secondary structures.

ELT field trial

Emergency locator transmitters (ELTs) now in service conform to a specification that has been in use for many years. These ELTs have exhibited a high false alarm rate and unreliable activation when involved in accidents. In the United States, the Federal Aviation Administration is planning to adopt more rigorous operational performance standards – TSO-C91a – for all future ELT installations.

A new generation of ELTs meeting these standards features a remote control indicator on the instrument panel that allows the pilot to monitor, test, activate, or reset the device from the cockpit. This should help to reduce the number of false alarms by allowing the pilot to reset the transmitter if it is activated inadvertently.

This in-house research project involves a comprehensive field trial of the new ELTs, to determine how well they can withstand the rigours of the Canadian climate, as well as routine operating conditions. Over one hundred aircraft, chosen as a representative sample of the Canadian general aviation fleet, will be equipped with new ELTs, and will participate in a two-year trial. Their owners will monitor the ELTs' performance (in compliance with the manufacturer's recommended inspections and maintenance) and report regularly to TDC. Following the trial, the ELTs will be inspected to see if any deterioration has taken place. The data obtained will indicate how well the transmitters withstand continuous vibration and the constant pressure and temperature changes brought about by climbs and descents.

Report: None to date
Schedule: September 1989 – March 1994
Funding:

National Search and Rescue Secretariat	$100 000
TDC	$52 000
Total	$252 000

Project Numbers: 6995, 6996, 6997
File Number: 1455-189-2
Project Officer: Howard Posluns

New generation ELTs will be evaluated in general aviation aircraft.

Aircraft ice monitor

The accumulation of ice on aircraft structures is a serious concern, and access to precise data would help personnel to make informed decisions on de-icing procedures.

This project has developed a prototype monitoring sensor that can accurately detect, measure, and classify surface contamination from frost, ice, and snow. Constructed of material similar in thermal and structural properties to that of the aircraft, the sensor can be flush mounted on those areas where an ice-free surface in flight is critical.

In follow-on work, researchers will construct and test proof-of-concept prototypes and subject them to ice tunnel and airborne testing.

Contractor: Instrumar Ltd., St. John's, Newfoundland
Report: Non-releasable, contains proprietary commercial information
Schedule: May 1989 - April 1990
Funding: $256 927
Project Numbers: 7273, 7275
File Number: 1455-211
Project Officer: Barry B. Myers

A ground deicing training session for boom operators
(Photo courtesy of Air Canada)

Investigation of anti-icing fluids

The AEA Type II anti-icing/deicing fluids in widespread use in Europe for protection of large jet aircraft are beginning to be used in North America. In conditions of freezing precipitation, Type II fluids have longer holdover times (time to re-freezing) than do traditional Type I fluids, thus extending the period that aircraft can safely wait before take-off. However, these fluids have a number of adverse aerodynamic effects on jet aircraft wings. Since they are not recommended for aircraft with low rotation speeds, it was thought that the fluids may require special application for commuter aircraft.

To obtain data on the effects of Type II anti-icing/deicing fluids on commuter aircraft aerodynamics, and to ascertain whether their advantages outweigh any disadvantages, researchers designed and constructed a model representing a typical turboprop commuter aircraft wing and flap. The model was tested under simulated winter take-off conditions, following application of Type II fluids, in NASA's Lewis Low Temperature Wind Tunnel in Cleveland, Ohio.

Based on these tests, acceptance criteria are being finalized and directives for application of the fluids and take-off procedures have been drawn up.

Contractor: de Havilland Aircraft of Canada Ltd., Downsview, Ontario
Report: None to date
Schedule: September 1989 - October 1990
Funding: $225 000
Project Number: 7489
File Number: 1455-216
Project Officer: Barry B. Myers

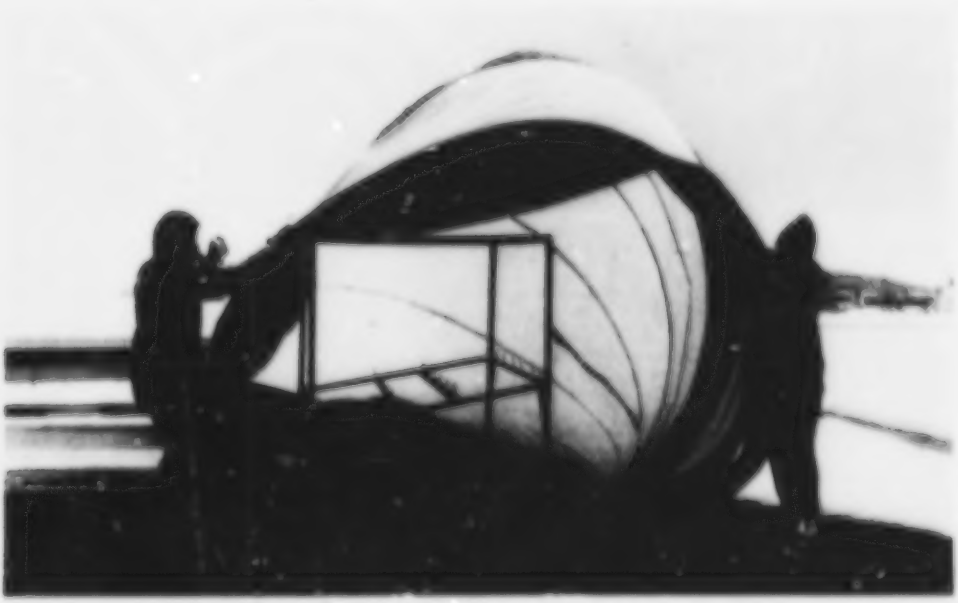
Testing of deicing fluids

Recent serious accidents, occurring at take-off during freezing precipitation, have led to increased research into the problem of eliminating ice or snow adherence to airfoils and control surfaces. The length of time during which anti-icing/deicing fluids are effective is influenced by wind conditions, temperature, and precipitation. No quantitative data is available to provide performance criteria for these fluids.

This project is developing test procedures to investigate icing in typical winter conditions and to assess the period of effectiveness of currently available fluids and new fluids entering the market. Field tests are being conducted at six sites in eastern Canada, as well as in the United States, Europe, and Japan. To be eligible for inclusion, proposed deicing fluids must undergo wind tunnel qualification tests at the Université du Québec in Chicoutimi.

TDC is coordinating the collection of data from all sites. After analysis, the results will be disseminated to the international aviation community.

Contractor: Aviation Planning Services Ltd., Montreal, Quebec
Report: None to date
Schedule: March 1990 - July 1991
Funding: $180 000
Project Number: 7697
File Number: 1455-227
Project Officer: Barry B. Myers



Workers mount a tent at the test site in St. John's. Panels coated with deicing fluids are placed on the rig and protected by the tent until testing begins.

Wet runway risk analysis

Following several recent incidents where large aircraft slid off wet runways, the Transportation Safety Board of Canada recommended research be undertaken to provide more information to help pilots determine take-off conditions. Current rules for such calculations apply to dry or saturated surfaces only – there are no intermediate measures. Additional information is required on the risks associated with ground roll and emergency braking in the case of an aborted take-off.

This project is designed to evaluate the merits of a number of countermeasures in reducing the risk of take-offs from wet runway surfaces. The performance of several types of commercial aircraft is being studied to establish the risks associated with different conditions and operations.

Researchers have identified a need to establish international agreement on criteria for contaminated runway friction measurement and are recommending that the costs and benefits of several countermeasures be evaluated. TDC is considering further action based on these findings.

Contractor: Sypher Mueller International Inc., Ottawa, Ontario

Report: *(Draft)* Aircraft take-off performance on wet and contaminated runways. Sypher Mueller International Inc., 1990

Schedule: August 1989 - March 1991

Funding: $205 812

Project Number: 7142

File Number: 1455-203-2

Project Officer: Barry B. Myers

Aircraft accident cost model

In 1981 TDC developed a model to assist Transport Canada's Aviation Group to calculate the cost of aircraft accidents. It operated on a Burroughs mainframe computer using 1976-79 accident data and 1981 costs.

This project is developing an updated and improved version of the model, to be operated on an IBM-PC, that will provide direct access to the accident data base maintained by the Transportation Safety Board of Canada. A major part of the work involves consultations with users of the current model to assess its limitations and to develop specifications for the system that will meet their needs and those of future users.

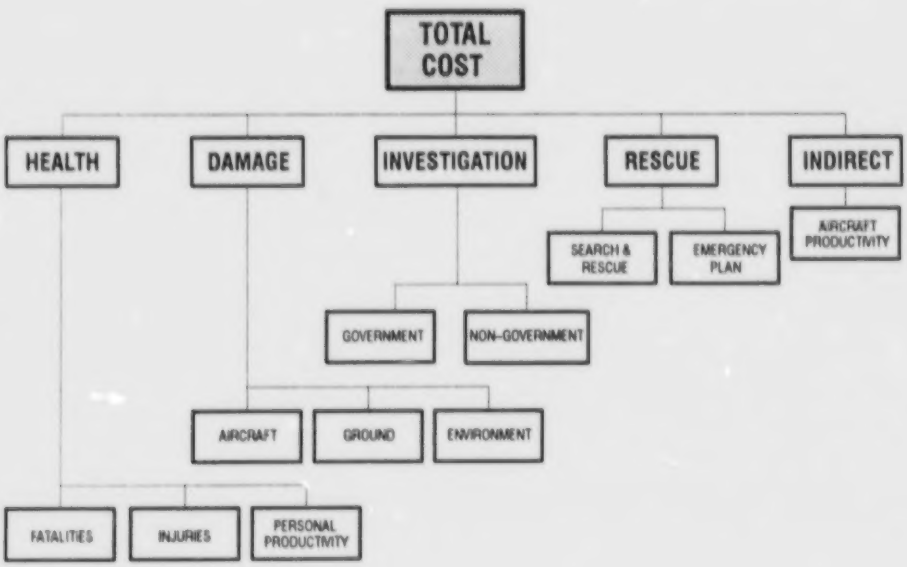
The updated model will be able to analyse the sensitivity and risks associated with selected factors and to provide the basis for cost-benefit analysis of proposed changes in safety regulations, procedures, and facilities.

It will be able to produce costs for a given profile of accident – for example, night-time accidents involving pilots with less than five years of experience. The model will use individual accident profiles to determine the values of key data elements, and the pertinent values will be totalled to obtain an overall cost.

Contractor: James F. Hickling Management Consultants Ltd., Ottawa, Ontario
Report: None to date
Schedule: February 1990 - March 1991
Funding:

TDC	$69 626
Transportation Safety Board	$15 000
Total	$84 626

Project Numbers: 7208, 7539, 7540
File Number: 1455-202
Project Officer: Arjan Chandan



Cost model structure

Shoulder harnesses for small aircraft

At present only half of Canada's small commercial aircraft have shoulder harnesses installed for the flight crew. At the request of the Airworthiness Branch of Transport Canada, TDC supported a study of the costs and benefits of implementing mandatory installation of shoulder harnesses for crew seats in all small airplanes and helicopters.

A review of accident data since 1976 provided the basis for an estimation of injury and fatality rates with and without the use of shoulder harnesses. Researchers concluded that shoulder harnesses effectively reduce both pilot fatalities and the severity of injuries in small aircraft and helicopter accidents.

A cost-benefit analysis to determine whether retrofitting shoulder harnesses in small planes and helicopters could be justified revealed that retrofitting would be cost-effective even in older aircraft, provided that they would remain in normal operation for several more years.

Contractor: Sypher:Mueller International Inc., Ottawa, Ontario

Report: TP 10525E, The regulatory and economic impact of mandatory requirements for shoulder harnesses in small commercial aeroplanes and commercial helicopters, Sypher:Mueller International Inc., 1990

Schedule: May 1989 - November 1990

Funding: $82 475

Project Number: 7257

File Number: 1455-183-3

Project Officer: William S.C. McLaren

Detection of overloaded aircraft

At the request of the Enforcement and Legislation Branch of Transport Canada's Aviation Group, TDC undertook testing of three weigh scales to determine the most effective scale for detection of overloaded aircraft. The project also investigated methods for detecting overloaded seaplanes, including float planes.

After selecting a scale manufactured by Haenni & Co. Ltd. of Switzerland, because of its accuracy, pad height and weight, and ease of operation, researchers conducted field trials to weigh aircraft in wind conditions, and developed a mathematical model for generating correction factors. Aircraft with a maximum gross weight of 65 000 lbs. were the focus of the study.

The trials demonstrated that the selected scale remained accurate under wind conditions, provided that the wind was relatively steady at 10 knots or less.

The study of methods for detection of overloaded seaplanes found that, in calm water, the gross weight of a float plane can easily be determined by measuring the waterline at two points on one side of each float.

Implementation of these methods should facilitate the enforcement of regulations and lead to a reduction in the number of overweight or unbalanced aircraft.

Contractor: Aviation Planning Services Ltd., Montreal, Quebec
Report: None to date
Schedule: January 1990 - May 1990
Funding: $50 000
Project Number: 7474
File Number: 1455-209
Project Officer: Sesto Vespa

Piper Cheyenne on Haenni System

Strobe light bird control

Birds are a considerable hazard to aviation, and while most bird strikes occur at take-off or landing, incidents involving aircraft moving at high speed have been reported. This can be very serious, since a bird weighing one pound hitting an aircraft flying at 300 knots has an equivalent force of about 3 000 pounds. A means to control birds, preferably by dispersing rather than destroying them, must be found. Research in Sweden and France has indicated that light may repel birds from aircraft.

In this project, researchers evaluated the use of an aircraft-mounted strobe light to prevent bird strikes. They studied the literature and data on the behavioural response of birds to light, and developed functional specifications for the most effective strobe equipment.

Since no strobe equipment on the market was found to meet these specifications, follow-on work supported by the Department of National Defence and Transport Canada's Airports Group will develop and evaluate an operational prototype. If this evaluation is positive, 30 units will be produced and installed for in-flight evaluation in Canadian aircraft over a two-year period.

Contractor: Delta Environmental Management Group Ltd., Calgary, Alberta
Report: None to date
Schedule: May 1989 - October 1993
Funding: $30 013
Project Numbers: 7281, 7461
File Number: 1455-121
Project Officer: Trevor N. Smith

Contractor: To be determined
Report: None to date
Schedule: June 1990 - October 1993
Funding:

National Defence	$200 000
TDC	$160 000
Airports Group	$40 000
Total	$400 000

Project Number: 7628
File Number: 1455-121
Project Officer: Trevor N. Smith

Airspace design expert system

In this project, research is continuing on an Airspace Design Expert System (ADES), a computer-based tool for the design of airways and instrument approaches. The system uses accurate terrain and obstacle data bases and incorporates airspace design rules. Featuring two-dimensional contour maps and three-dimensional displays of terrain and approach navigation features, it will help designers to determine the best location and orientation for runways, approach paths, and flight corridors. ADES simulates flights through 3D terrain in any direction, enabling users to inspect any rule infringements identified by the expert system.

ADES has several additional applications, including the exploration of criteria for design related to new navigational aids, the exploration of modified criteria related to the new approaches feasible with microwave landing systems, and cockpit displays for integrating approach features with instrument readouts.

A related project tested the use of SPOT satellite imagery to provide essential digital terrain elevation data (DTED) for ADES. SPOT-derived DTED and images can provide photo-realistic terrain views as well as land cover classification.

Contractors: Virtual Prototypes Inc., Montreal, Quebec and Horler Information Inc., Ottawa, Ontario

Reports: *(From earlier research)* TP 9601E, An airspace design system using a graphics workstation – the pilot project, Virtual Prototypes Inc., 1988

TP 10651E, Feasibility of using satellite imagery in ADES, Horler Information Inc., 1990

Schedule: July 1989 - October 1992

Funding:

TDC	$532 549
Aviation Group	$532 549
Total	$1 065 098

Project Numbers: 7159, 7505, 7522, 7523

File Number: 1455-177-4

Project Officer: Barry B. Myers

The screen above shows an approach being designed for the MLS site at Pemberton, B.C. At left, a contour map of the Pemberton valley has a detail of the terrain superimposed.

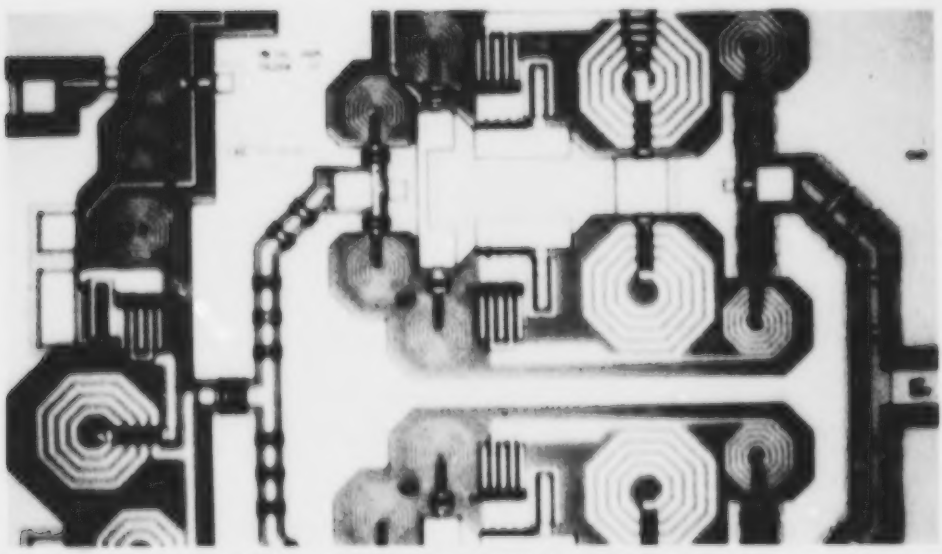
Monolithic microwave integrated circuits in MLS

The antenna configuration of current MLS units, while simple, has some disadvantages. The presence of high power densities in the centralized transmitter and phase shifters increases the failure rate of the components. In the absence of a backup, failure of the transmitter would result in a complete shut-down of the system. Transmission modules based on monolithic microwave integrated circuits (MMIC) could be used in MLS antennas to prevent such a shut-down.

Transport Canada is undertaking a long-term development program to establish Canadian production and testing of MMIC. MMIC technology will allow the integration of microwave components on gallium arsenide wafers. (Gallium arsenide is a semiconductor that combines gallium and arsenic.) Such miniaturization promises increased reliability, reduced power consumption, and better signal control.

Working with the Communications Research Centre of the Department of Communications, researchers are developing MMIC chips for use in MLS antennas. The chips operate at microwave frequencies and may be used to generate and steer MLS fan-shaped beams. Preliminary phase shifter and power amplifier designs have been developed, and future work will consist of integrating the resulting chips into modules suitable for inclusion in MLS phased-array antennas for testing and evaluation purposes.

Contractor: Department of Communications, Communications Research Centre, Ottawa, Ontario
Report: None to date
Schedule: October 1987 - April 1992
Funding: $1 031 200
Project Number: 7364
File Number: 1455-153-9
Project Officer: Louis A. Poulin



Power amplifier stage of MMIC module targetting the MLS ground equipment

MLS hardware monitor

This project is undertaking several developmental activities to ensure that Canadian MLS equipment conforms to performance specifications and standards required by the International Civil Aviation Organization (ICAO). Work includes the development of an independent hardware monitor as a back-up to the software monitor, and the development of several hardware and software sub-systems.

Researchers are studying the reliability and integrity of Canadian MLS equipment, analysing both failure mode effects and criticality in accordance with international specifications, and designing a new azimuth corporate feed to ensure that the microwave circuits maintain their characteristics over the full functional temperature range. Environmental tests will assess the sensitivity of MLS to temperature and humidity.

Following completion of certification tests to meet ICAO's standards, Transport Canada will ensure that the equipment meets its operational requirements.

Contractor: Micronav International Inc., Sydney, Nova Scotia
Report: None to date
Schedule: October 1988 - April 1991
Funding: $339 664
Project Number: 7054
File Number: 1455-153-7
Project Officer: Micha Avni

Precision distance measuring equipment interrogator

MLS, the new international aircraft guidance system scheduled to be in operation in 1998, will make use of precision distance measuring equipment (DME/P) transponders. This sensitive equipment will require extensive on-site engineering testing and inspection.

At present there are no interrogators on the market that could be used to make such tests. In this project, researchers analysed user requirements, compiled technical specifications, and produced a conceptual design of hardware and software sub-systems. The design incorporated flight inspection requirements for Transport Canada. The project also provided a detailed cost estimate for subsequent development and implementation phases.

The project demonstrated that the development of the interrogator is technically feasible. Production of the interrogator will depend on market demand, which is closely tied to the widespread introduction of MLS approach procedures requiring DME/P equipment.

Contractor: Canadian Marconi Company, Montreal, Quebec
Report: Non-releasable, contains proprietary commercial information
Schedule: January 1989 - April 1990
Funding: $120 000
Project Number: 7134
File Number: 1455-184-3
Project Officer: C. Alfred Versailles

Phase centre determination of MLS antenna systems

Before being installed by Transport Canada in Canadian airports, microwave (MLS) antennas are tested under controlled conditions. Since these ground tests are conducted at medium range (a few hundred metres), the precise location of the phase centre of the antenna must be determined accurately.

Until now, correction formulas and interpretation of test results have assumed certain values for the phase centre that were not based on analysis. As a result, anomalies in the behaviour of the beam have been attributed, at times, to inaccurate assumptions of phase-centre location. This project attempted to provide a sound scientific basis for this aspect of MLS testing by using mathematical modelling to investigate the phase centre of MLS antennas under scan conditions. It also studied environmental effects on the phase centre.

The project resulted in a general mathematical model that can be used to locate the phase centre of any antenna. Analysis showed that no real antenna can be represented fully by a mathematical model having the exact amplitude and phase distributions specified by theory. In practice, production tolerances, environmental conditions and other factors have a significant effect on the amplitude and phase distributions across the array. In turn, these factors can seriously affect the location of the antenna's phase centre. Therefore, any medium-range measurements of MLS arrays on the ground must be conducted and interpreted with these constraints in mind.

Contractor: University of Manitoba, Winnipeg, Manitoba

Report: TP 10517E, Phase centre determination of MLS antenna systems, phase I, University of Manitoba, 1990

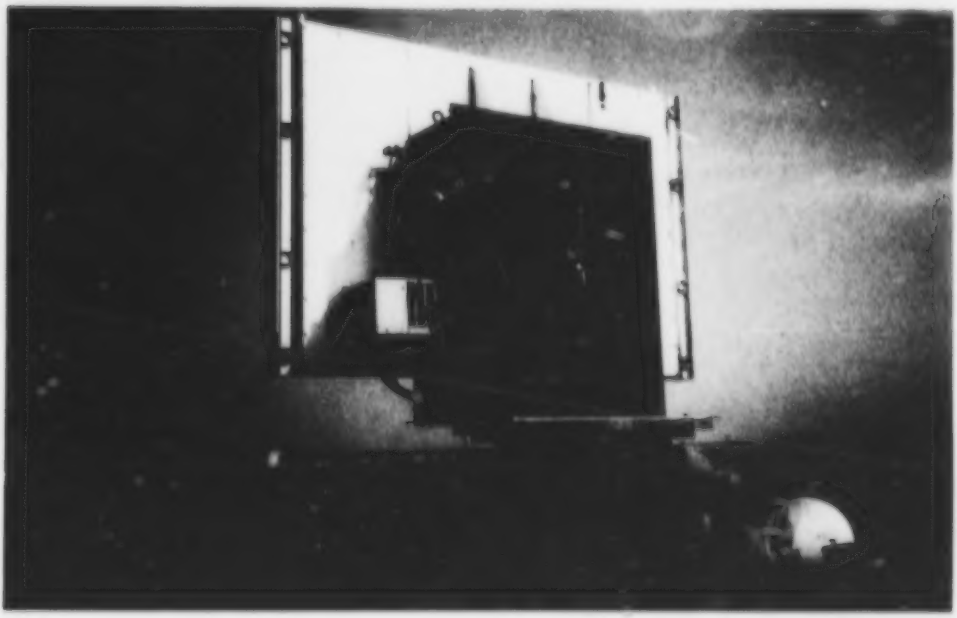
Schedule: July 1989 - September 1990

Funding: $82 970

Project Number: 7327

File Number: 1455-153-8

Project Officer: Micha Avni



MLS antenna

Future air navigation systems

Future Air Navigation Systems (FANS), a concept currently under study by the International Civil Aviation Organization (ICAO), is designed to overcome the limitations of the existing system and to meet the future needs of international aviation through the integration of communications, navigation, and surveillance related to air traffic management.

This project resulted in seven technical papers presented by the Canadian delegation on the special ICAO committee on FANS to the Working Group meeting in May 1990. Topics included a proposed model contract for Aeronautical Mobile Satellite Services (AMSS); a description of an AMSS system; a discussion of cost-benefit factors in the implementation of FANS; and considerations of the Canadian airspace system and international air traffic management.

In addition, a study initiated as part of this project is now investigating the use of satellites as a cost-effective answer to the future needs of air navigation.

Contractor: Thompson-Hickling Aviation Inc., Ottawa, Ontario
Report: Unpublished technical papers
Schedule: January 1990 - March 1992
Funding: $124 377
Project Numbers: 7496, 7694
File Number: 1455-217
Project Officer: Louis A. Poulin

Expert system for weather forecasts

The objective of this project is to design, develop, and test a prototype expert advisory system, STRATUS, to help aviation meteorologists to provide airports with accurate low cloud forecasts. The system has the potential to reduce labour needs while enhancing aviation safety.

Basing their calculations on the fundamental physical rules governing the formation of low clouds, researchers are modelling weather phenomena. STRATUS addresses two independent processes: the forecasting process, which simulates the time evolution of atmospheric factors affecting low cloud formation; and the diagnostic process, which analyses these factors at a specific time to determine the low cloud coverage.

The diagnostic module has proved successful in detecting cloud ceiling, the height of the ceiling, and the percentage of cloud cover. The project team is now refining the forecasting module and has completed the first prototype.

Contractor: Centre de recherche informatique de Montréal (CRIM), Montreal, Quebec

Report: *(From earlier research)* TP 10204F, Développement d'un système expert pour les prévisions météorologiques des aéroports, CRIM, 1990

Schedule: March 1990 - August 1991

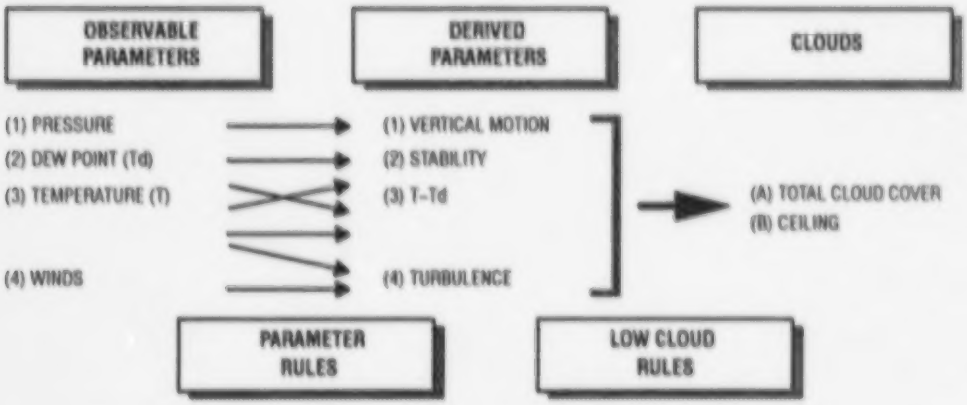
Funding:

Industry, Science and Technology Canada	$419 000
TDC	$125 000
Aviation Group	$115 000
Atmospheric Environment Service	$62 000
National Defence	$42 000
Total	$763 000

Project Numbers: 7421, 7422, 7423, 7424

File Number: 1455-215

Project Officer: Howard Posluns



STRATUS diagnostic process

Computer-aided learning system for electronics technicians

Air traffic control electronics technicians, who maintain radar and communications systems, currently receive off-site training to keep them up-to-date with technological advances. Use of a mobile, computer-aided learning (CAL) workstation could make refresher courses available at the workplace.

In an associated project, researchers studied the ergonomic design and use of workstations. Following evaluation of three designs, a full size mock-up was constructed.

This project is now developing a prototype workstation, on the basis of the mock-up, and equipping it with two CAL software packages. The system will be evaluated for learning effectiveness and ergonomic suitability, and results will enable Transport Canada's Aviation Group to establish guidelines for future CAL workstation designs.

Contractor: Sypher Mueller International Inc., Ottawa, Ontario

Report: *(From earlier research)* TP 6742E, Ergonomically designed workstation for training of electronic systems maintenance technicians, 2 vols., Sypher Mueller International Inc., 1988

Schedule: February 1990 - December 1991

Funding:

TDC	$586 043
Aviation Group	$250 000
Total	$836 043

Project Numbers: 7282, 7283, 7284

File Number: 1355-166

Project Officer: Ruth M. Heron

Prototype computer-aided learning workstation

MEG tomography system

Selecting suitable candidates from the large number of applicants for training as air traffic controllers is difficult, time consuming, and costly. An accurate measure of reaction to stress would help to narrow the field.

This project is developing a multichannel magnetoencephalographic (MEG) tomography system capable of reading the activity of the entire brain simultaneously. The current flows that it records appear to reflect motor, sensory, and cognitive functions.

After determining the system's capacity to detect changes that can be linked to deficits in attention and arousal resulting from long-term sleep deprivation, researchers used MEG to analyse the effects of sleep deprivation and other factors on operators whose jobs require high levels of attention and skill.

The results of this analysis are being used to develop the system as a means of identifying individuals who can maintain high performance in stressful environments.

Contractor: CTF Systems Inc., Port Coquitlam, B.C.

Subcontractor: Brain Behaviour Laboratory, Simon Fraser University, Burnaby, B.C.

Report: *(From previous research)* TP 7508E, Magnetoencephalographic signals: source location, Brain Behaviour Laboratory, Simon Fraser University, 1987

Schedule: November 1988 - May 1990

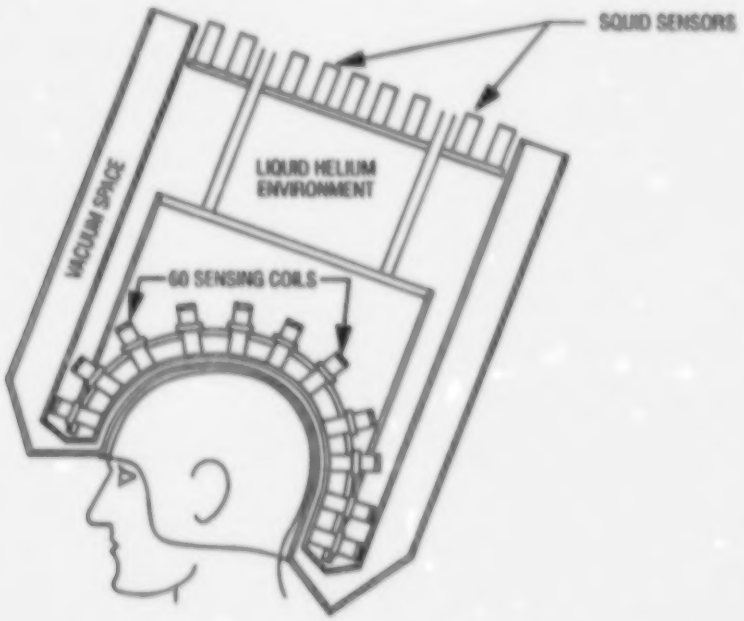
Funding:

Supply and Services Canada	$600 000
National Defence	$160 000
CTF Systems Inc.	$104 553
TDC	$100 000
Total	$964 553

Project Number: 7191

File Number: 1450-146-2

Project Officer: Ruth M. Heron



Artist's sketch of MEG system

Expert system advisor for the resolution of air traffic conflicts

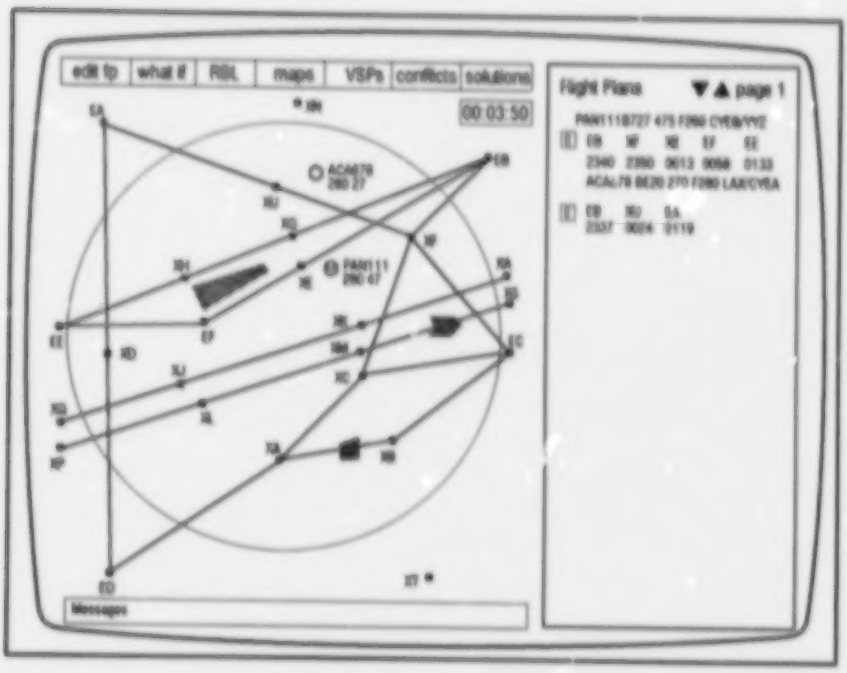
Violation of safe separation distances between aircraft can be attributed to both equipment failure and human error. An expert system incorporating the knowledge and judgment of experienced controllers and pilots could offer timely and consistent advice under a range of operational conditions. Recent developments in knowledge-based systems enhance the prospects of their application to air traffic control and related planning and training.

This project is developing two such expert systems: one aimed at conflict resolution planning, based on flight plan information; the other at tactical conflict resolution based on radar target data acquired in real time. The latter system will use existing non-radar algorithms that can be adapted to tactical response requirements.

Contractor: CompEngServ Ltd., Ottawa, Ontario
Report: None to date
Schedule: November 1989 - December 1991
Funding:

TDC	$556 102
Industry, Science and Technology Canada	$260 000
Total	$816 102

Project Number: 7339
File Number: 1455-200-2
Project Officer: Yves Le Borgne



This sketch of a controller's display for the conflict resolution expert system shows flight plan data.

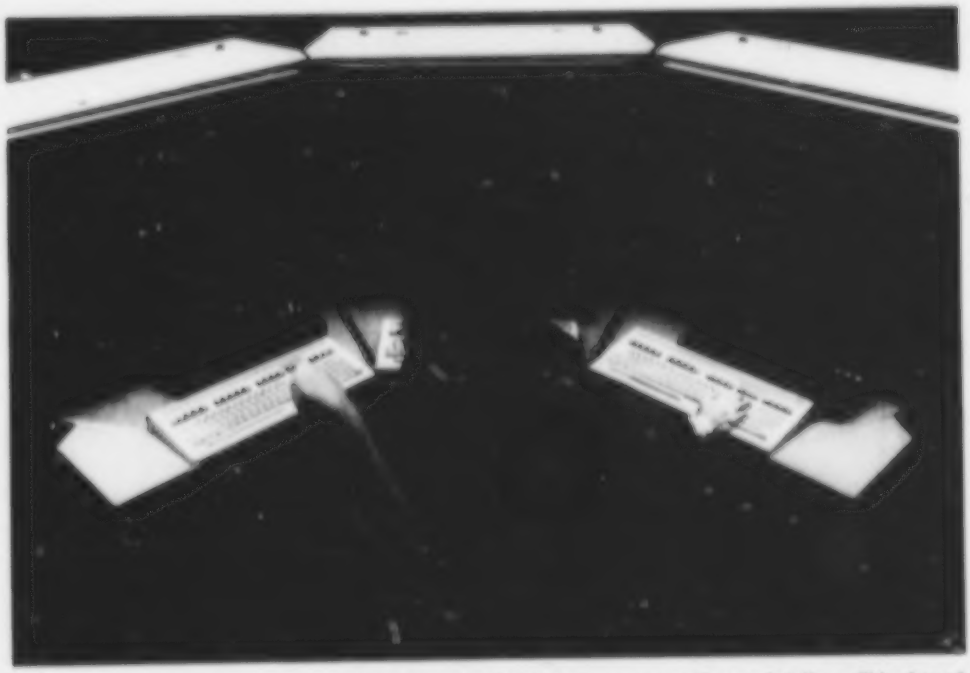
Display of meteorological data for air traffic control

Safe and efficient flights depend on accurate and timely weather information. A vast amount of weather information is already available to air traffic controllers, and the Canadian Automated Air Traffic System (CAATS), to be operational in the mid 1990s, will provide even more. A standardized controller workstation will be a major part of CAATS. It will present digital radar, a flight plan, weather data on very high resolution, and large-screen colour displays using advanced raster graphics technology.

This project aims to identify the weather information valuable to air traffic controllers, and to determine the best method for its display. Using the CAATs workstation, researchers began by reviewing the existing and projected information available from Environment Canada's Atmospheric Environment Service, as well as from other national and international agencies.

All air traffic control functions are being analysed, and the weather information required for each function and automated system is being defined and classified. To avoid information overload, each item to be included in the display must be justified. After compiling the data, researchers will develop a presentation tailored to the needs of ATC personnel.

Contractor: MacDonald Dettwiler and Associates, Richmond, B.C.
Report: None to date
Schedule: January 1990 – June 1991
Funding: $106 899
Project Number: 7329
File Number: 1455-174-3
Project Officer: Howard Poeluns



The proposed CAATS common controller workstation will be based on the Hughes AMD-44 product line.

Use of colour in ATC displays

As their range of tasks expands, new technology is being sought to assist air traffic controllers in coping with their workloads. This project investigated the use of colour in the displays of air traffic control (ATC) workstations, with a view to optimizing work performance, while minimizing fatigue and work-related stress.

After searching the international literature on video displays and ATC display design, researchers analysed the many technical factors and problems associated with the application of colour to functional display screens. The characteristics of human vision, ergonomics, available display technologies, presentation of the display, and the nature of ATC tasks were also taken into account.

Researchers then prepared guidelines for the selection and number of colours, luminance and brightness of displays, contrast and legibility, symbol size, and control of brightness and contrast on the screen.

The Aviation Group of Transport Canada has forwarded the report to the U.S. Federal Aviation Authority as part of an information exchange under a Canada-U.S. agreement.

Contractor: Thompson-Hickling Aviation Inc., Ottawa, Ontario

Report: TP 10532E, The use of colour on air traffic control displays, Thompson-Hickling Aviation Inc., 1990

Schedule: January 1990 - November 1990

Funding: $65 158

Project Number: 7330

File Number: 1455-174-2

Project Officer: Roy S. Nishizaki

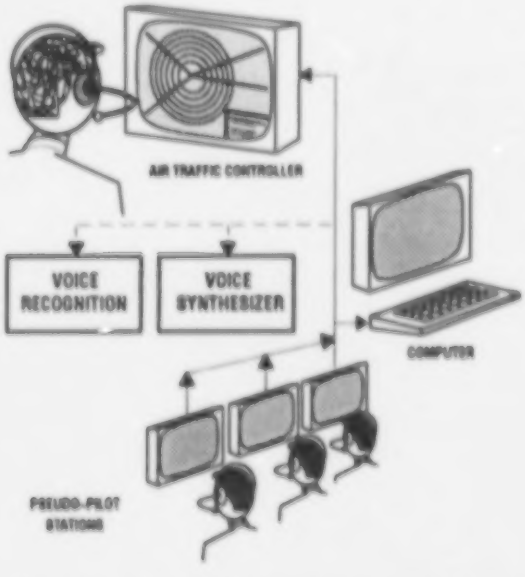
Voice entry system for air traffic control

In this project researchers investigated the integration of state-of-the-art voice recognition equipment into air traffic control (ATC) operations, with the intent of replacing keyboard entry by automatic voice input. The development of a prototype voice entry system will assist the Aviation Group's Research and Experimentation Centre in their examination of new tools for ATC training. The systems selected for use with voice technology were the Operational Information Display System and the Visual Information Processor. The target applications included the replacement of keypad/mouse entry at controller workstations and the possible replacement of the pseudo-pilot workstation. These applications required a vocabulary of 500 words and a syntax network of 400 nodes.

In ATC operations, speech recognition technology could supplement data entry via a keyboard for logging aircraft arrival and departure times, controlling runway lighting, and retrieval of weather and runway conditions. It could also be used to monitor the controller's side of controller-pilot dialogues for clearance to land, to take off, or to cross a runway. Since studies have shown that a large proportion of aircraft incidents are the result of runway intrusions, any aid to controllers for verifying runway clearances would help to improve safety.

The development of the voice entry system included a definition of system requirements, hardware selection, system design, software integration, and evaluation. The evaluation showed that the system correctly recognized 89 percent of speech templates. The project resulted in the development of a voice input/output demonstration system for pseudo-pilot replacement. The system is being considered for use in ATC radar training and in the ATC language laboratory.

Contractor: CAE Electronics Ltd., Saint-Laurent, Quebec
Report: *(Draft)* Development of a prototype voice entry system for ATC, CAE Electronics Ltd., 1991
Schedule: September 1988 - November 1990
Funding: $328 394
Project Number: 7050
File Number: 1455-201
Project Officers: James Reid, Yves Le Borgne



Voice entry system would replace the pseudo-pilot workstation.

Canadian radionavigation requirements

Several major initiatives have been undertaken recently in Canada and the United States to re-assess radionavigation technologies and their prospective uses. The development of navigation systems with broad application, such as Global Positioning Systems, and the increased demand for radionavigation services for marine, surface, and air uses have created a need for a consistent approach in Canada, similar to the United States National Radionavigation Plan. Without such a long-term assessment, systems may be duplicated, and their management may prove problematic.

The goal of this project was to analyse the radionavigation services likely to be offered to Canadian users, and to examine the possibility of providing a coordinated approach to these services. The systems were grouped as current surface-based radionavigation systems (e.g., LORAN-C, Doppler Radar, Advanced Train Control Systems); current satellite-based radionavigation/location systems (e.g., GEOSTAR, SARSAT); and future systems, such as GPS, MSAT, NAVSAT.

Researchers prepared a description of surface user requirements for radionavigation, surveyed equipment suppliers, and interviewed experts in this field as well as current and potential users. An estimate of the current use of radionavigation/location equipment and a forecast for the extent of use by the year 2000 were developed on the basis of this data.

Contractor: Thompson-Hickling Aviation Inc., Ottawa, Ontario

Report: TP 9452E, Radionavigation/location requirements for surface users in Canada: present and future, Thompson-Hickling Aviation Inc., 1989

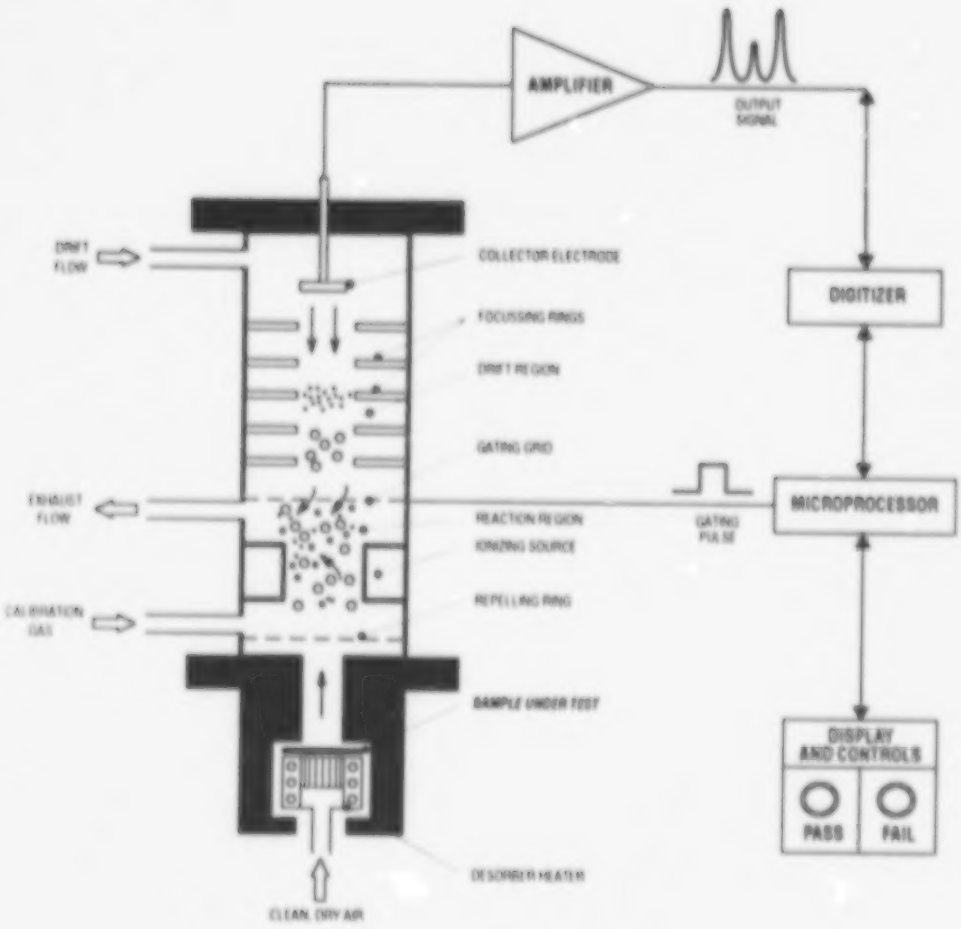
Schedule: September 1987 - January 1990

Funding: $165 000

Project Number: 6931

File Number: 1455-192

Project Officer: Barry B. Myers



IMS explosives sniffer operation

Ion mobility spectrometry explosives sniffer

The increasing threat of explosives at airports and on board aircraft has created an urgent need for screening devices capable of rapid detection. This project refined the key components of a pre-prototype ion mobility spectrometry (IMS) sensor developed in earlier research supported by TDC.

First developed as a narcotics detector to assist customs and law enforcement agencies in the detection of illegal drugs, the device operates like a vacuum cleaner, pulling particles of air into the instrument, where they are ionized. Since ions have different sizes and polarity, they move at different velocities down the small drift tube. The sample can thus be compared to drift times for known illegal materials and substances.

Project results indicated that the sensor can effectively detect the presence of explosives within six seconds. Researchers evaluated the system's potential and determined how it could be integrated into regular X-ray inspection equipment.

Contractor: Barringer Research Ltd., Rexdale, Ontario
Report: Non-releasable, contains proprietary commercial information
Schedule: October 1988 - November 1990
Funding: $249 362
Project Number: 7102
File Number: 1455-173-4
Project Officer: Maurice Audette

Barringer Instrument's **Ionscan detector** *uses ion mobility spectrometry.*

Automated X-ray screening

Improved screening of passengers' carry-on baggage is an important objective for Transport Canada. Automated detection of dangerous objects is being investigated as a means of increasing security and reducing operating costs by expanding the screening channel's capacity to process baggage.

This project was designed to develop a prototype of a real-time, computer-assisted X-ray screening system. The interpretation of X-ray images can be difficult and requires a high level of concentration. The proposed system highlights suspicious objects, primarily guns and knives, by outlining them in colour. A warning beep accompanies this detection. The operator may then use touch-screen icons to examine suspicious areas by means of various image-processing techniques. Transputers (computers with several processing units) do most of the processing, while a personal computer controls the system.

The prototype system met the goal of processing 12 bags per minute and tagged approximately 15 percent of bags for hand search. The probability of detection for guns was about 90 percent. While the false alarm rate was 10 percent, the items detected were unusual and warranted a hand search. Personnel quickly learnt how to use the system, and found it easy to operate.

Follow-on work is under way to improve the system's capability, particularly for the detection of bombs and dangerous materials.

Contractors: Array Systems Computing Inc., Downsview, Ontario and Techno-Scientific Inc., Woodbridge, Ontario

Report: TP 10065E, A computer-assisted X-ray screening system, Array Systems Computing Inc., and Techno-Scientific Inc., 1990

Schedule: May 1988 – August 1990

Funding: $583 288

Project Number: 6918

File Number: 1455-158-3

Project Officer: Maurice Audette

X-ray screening system indicating the presence of a pistol

Vapour laser preselector

The goal of this project is to improve the performance of current explosive vapour detection systems based on ion mobility spectrometry and gas chromatography. Work is directed at increasing the concentration of explosive molecular compounds after air samples have been taken, but before the molecular analysis and detection stage.

In conventional vapour detection systems, the adsorbent is globally heated to desorb the constituent molecules. Some selectivity of molecular compounds can be achieved by varying the gas temperature, but the response time is slow due to the adsorbent thermal mass. In the proposed system, the discrete nature of infrared absorption characteristics of molecular compounds is exploited and, as a result, a much higher selectivity and a faster response time are expected.

In the first phase of the project, physical parameters controlling the laser desorption process were studied, using a continuous wave laser. The project has demonstrated the feasibility of thermal desorption using an infrared laser and has confirmed its potential for replacing the conventional heat source in current explosives detection systems.

The second phase of the project is employing tunable pulsed lasers to selectively desorb vapour molecules in order to achieve the level of concentration required for the detection and identification of trace quantities of explosives in large volumes of ambient air.

Contractor: CPAD Holdings Ltd., Nepean, Ontario
Report: Non-releasable, contains proprietary commercial information
Schedule: December 1990 - September 1991
Funding: $593 349
Project Numbers: 7354, 7469
File Number: 1455-219
Project Officer: Louis A. Poulin

Passenger screening stations

Transport Canada is responsible for all facets of airport security, including the provision of inspection equipment and facilities.

In this project researchers are assessing the passenger screening stations at Canadian airports in order to identify more efficient and effective configurations and practices.

The project team is visiting fifteen airports across Canada to observe screening procedures and identify "bottlenecks", to record the configuration of equipment, to assess the effectiveness of the screening point configuration, and to monitor passenger processing rates through each of the security components: baggage X-ray, walk-through, and hand-held metal detector.

The results of this analysis will be used to develop recommendations for improved layouts and locations for screening stations in each of the airports studied.

Contractor: Sypher Mueller International Inc., Ottawa, Ontario
Report: None to date
Schedule: October 1989 - March 1992
Funding: $77 805
Project Number: 7520
File Number: 1455-217
Project Officer: Louis A. Poulin

Airside capacity planning model for Vancouver Airport

Airside capacity at Vancouver International Airport is a pressing concern. The airport routinely handles over 1 000 flights a day, reaching an hourly peak of over 80 flights. Airside facilities include two crossing runways, only one of which can be used under instrument flight rules. Poor weather can reduce capacity by as much as 40 percent, creating flight delays and backlogs as well as overflowing terminal facilities. Transport Canada has instituted the Airside Capacity Enhancement Project to determine what changes to facilities and operating procedures are needed to satisfy capacity needs through the year 2000.

The capacity problem at Vancouver presented an excellent test case for a new simulation technology that promises to provide an effective and easy-to-use planning tool. Researchers are developing a prototype model capable of assessing the effect on airside capacity of changes to airport configuration (runways, taxiways, and turn-offs), operating procedures, and air traffic demand. Using an object-oriented programming environment, visually interactive simulation models are created and the results are compared with traditional techniques for modelling planning and logistics problems related to transportation capacity.

The prototype model, run on an IBM-PC, simulates actual or projected traffic. The user can specify probability distributions associated with total number of flights, traffic mix, and weather conditions, and can intervene during the simulation to alter assumptions. The model uses graphic and animation techniques to present the results.

Contractor: Institute for Information Technology of the National Research Council, Vancouver, B.C.

Report: None to date

Schedule: February 1990 – March 1991

Funding:

TDC		$80 000
National Research Council	(in-kind)	$40 000
Airside Capacity Enhancement Project	(in-kind)	$40 000
Total		$160 000

Project Number: 7455

File Number: 1455-222

Project Officer: Brian Marshall

Sealing rock outcrops at Halifax International Airport

Halifax International Airport is built on a highly mineralized pyritic slate bedrock. When exposed to air and water, this rock releases extremely acidic and metal-laden effluent that has been proven to kill aquatic life in surrounding streams. During construction of the airport in the 1950s and in continuing development of the facility until 1982, large cuts were made in the slate bedrock, leaving areas of exposed or thinly-covered bedrock and other areas of fractured slate fill. These areas continue to discharge toxic runoff into the surrounding river systems. One of the simplest and most effective solutions is to cover the exposed rock surfaces with a low permeability capping material.

An earlier project to test and evaluate sealants determined that cement-based wet shotcrete and geopolymer systems were the most promising.

In this project, researchers at the Canadian Centre for Mineral and Energy Technology have developed a polypropylene fibre-reinforced, high-volume, fly ash shotcrete system for capping the rock outcrops. This system has low cement content, and incorporates large volumes of low-calcium fly ash and large percentages of polypropylene fibres. The concrete can be placed using conventional techniques.

Field investigations at the airport commenced following the installation of four test panels in the fall of 1989 and were extended to include two further panels in the spring of 1990. The performance of the sealants is being closely monitored.

Contractors: Canada Centre for Mineral and Energy Technology (CANMET), Ottawa, Ontario and W.S. Langley and Associates, Halifax, Nova Scotia

Sub-contractors: Hardy BBT Ltd., Burnaby, B.C. and D. Connie Consultants Ltd., Mississauga, Ontario

Report: (Draft) TP 10426E, Development and evaluation of capping systems for sealing pyritic slate outcrops at the Halifax International Airport, CANMET, 1990

Schedule: September 1988 - May 1991

Funding: Airports Group $246 530

Project Numbers: 7165, 7361

File Number: 1455-208

Project Officers: Doug W. Dibble, Wayne G. Rowan

Application of shotcrete

Airport noise management strategies

Increasing demand on the air transport industry is straining runway and terminal capacity, and creating problems such as noise pollution. Airport managers must balance business needs with the needs of the surrounding community.

In this project, researchers first identified noise management policies worldwide. They found that most countries, including Canada, do not have formal policies regarding airport noise. Using Pearson International Airport for a case study, the project team developed cost-effective noise management guidelines for Canadian airport managers, proposing a matrix of strategies with specific recommendations depending on the nature of the noise and the type of airport.

The strategies include noise "budgets", noise-related landing fees, and the establishment of a complaint mechanism. The guidelines will help airport managers to identify pertinent issues and technologies and to determine the costs and benefits of each strategy.

Contractor: DWG Research Associates Ltd., Waterloo, Ontario
Report: TP 10118E, The management of airport noise, DWG Research Associates Ltd., 1990
Schedule: November 1988 - September 1990
Funding: $20 000
Project Numbers: 7177, 7179
File Number: 1455-208
Project Officer: Trevor N. Smith

Landing patterns on narrow airstrips

Air transportation is the best means of access to most communities in the Canadian North. Many small airstrips exist and more are needed. Yet the cost of upgrading existing runways or building new ones is beyond the reach of these remote communities.

This project to develop construction guidelines for safe, low-cost runways focussed on runway width. If widths can be reduced without sacrificing safety, construction costs could be lowered.

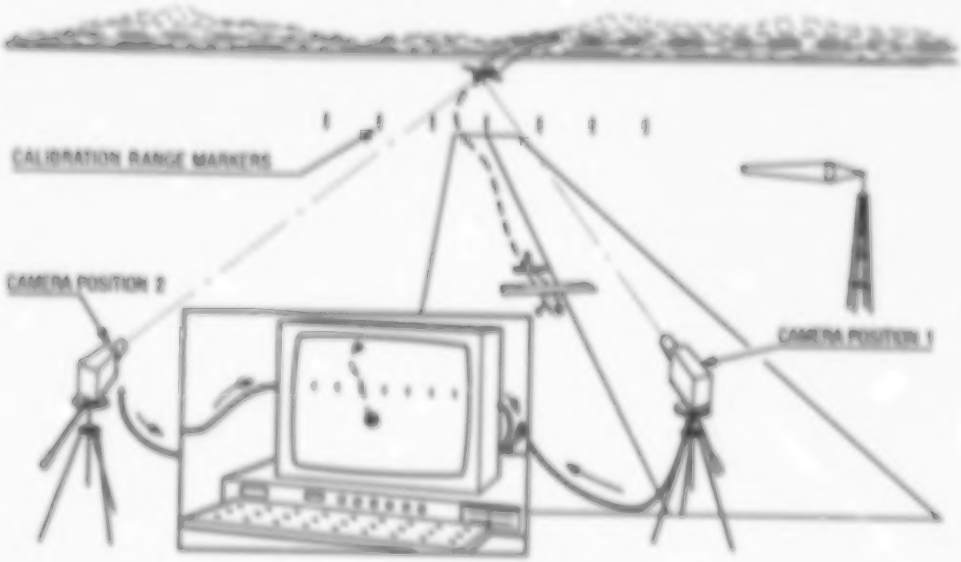
Researchers developed a method of measuring the landing behaviour of small aircraft using a video recording system to digitally record data on aircraft landings under a variety of cross-wind conditions. They also compared methods of data collection to establish performance/cost relationships. Proof-of-concept field trials confirmed the results of aircraft landing simulations carried out in the laboratory.

The project demonstrated the feasibility of accurately tracking aircraft landings over a range of weather conditions including high winds and temperatures descending to -10 degrees. Refinements to the system are under consideration.

Contractor: R.S. Wallace & Associates Ltd., Merrickville, Ontario
Report: None to date
Schedule: January 1998 - March 1999
Funding:

Supply and Services Canada	$240 387
TDC	$245 612
Airports Group, Department of Indian and Northern Affairs, and Government of the Yukon	$70 000
Total	$555 209

Project Number: 7004, 7005, 7010
File Number: 1455-106
Project Officer: Barry B. Myers



Recording landing dispersion of light aircraft

Computer modelling of nacelle aerodynamics

Improved nacelle design could lead to enhanced aircraft performance, through a reduction in airframe drag, increases in propeller efficiency, and consequently improved fuel efficiency. A computer model called VSAERO can predict the three-dimensional flow around a nacelle and into an engine air intake, permitting the design of new nacelles with greatly reduced need for costly, time-consuming wind tunnel testing.

Earlier work sponsored by TDC investigated improved designs of turboprop engine intakes using the VSAERO code and wind tunnel testing. In this project, researchers are seeking to develop a means to reduce nacelle drag, improve the design of propeller blade cuffs, and investigate the aerodynamics of tractor and pusher propeller installations. Researchers are continuing the analysis of propeller-nacelle interaction using the VSAERO code, and verifying the results by wind tunnel testing. Work includes the design of test rigs for tractor and pusher wind tunnel tests, the manufacture of propellers and test rigs, and wind tunnel calibration tests.

This research will provide a better understanding of the aerodynamics of nacelles, and should lead to reduced fuel consumption through improved design of propeller-nacelle configurations.

Contractors: de Havilland Aircraft of Canada Ltd., Downsview, Ontario and Pratt & Whitney Canada Inc., Longueuil, Quebec

Reports: (From earlier research) TP 9888E, Design and wind tunnel test of an advanced engine intake for a turboprop nacelle configuration, de Havilland Aircraft of Canada Ltd., 1988

TP 90125 (2 vols.), Nacelle aerodynamics research - phases I and II interim report, Pratt and Whitney Canada Inc., 1988

TP 90156, Nacelle aerodynamics research, Pratt and Whitney Canada Inc., 1988

Schedule: November 1988 - March 1991

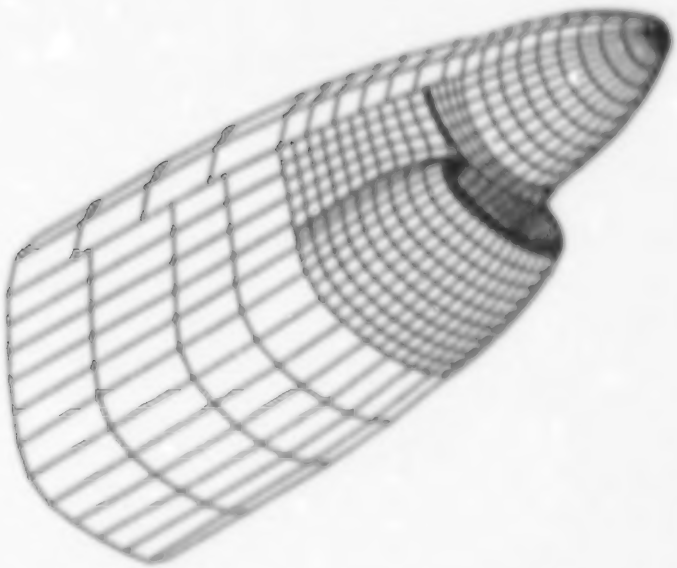
Funding:

Energy R&D Program	$413 675
Industry	$400 000
Total	$813 675

Project Numbers: 7057, 7058

File Number: 1455-112

Project Officer: C. Alfred Vanasse



Computer models are used extensively in the nacelle research program.

Tilt-rotor/Vertiport planning and development study

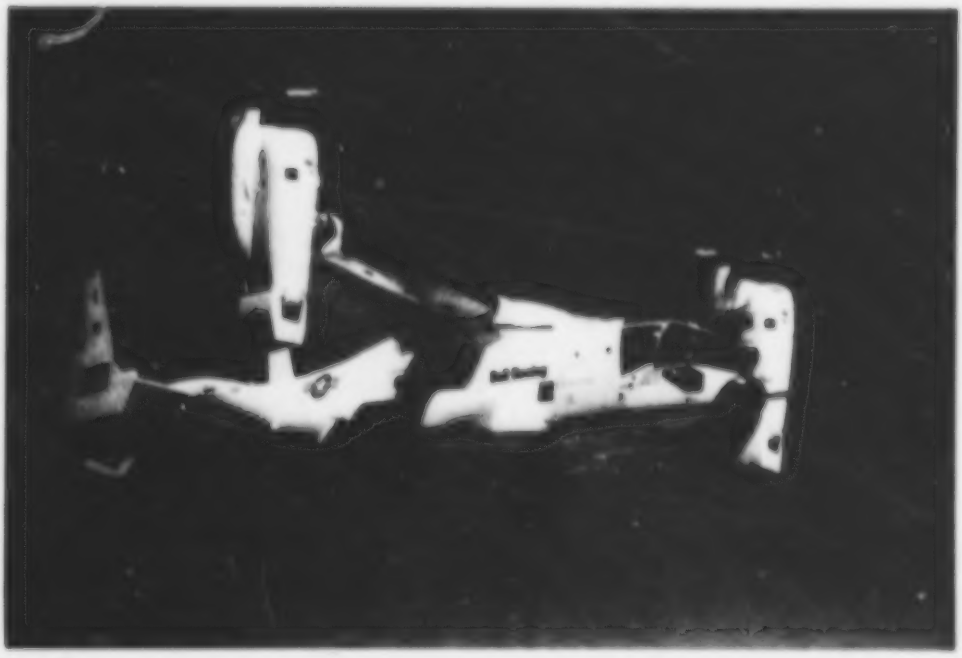
Runway capacity is an increasingly serious problem at major Canadian airports, as it is throughout North America. However, providing additional capacity for the existing system is prohibitively expensive. Vertical Take Off and Landing (VTOL) aircraft, with their dramatically reduced ground and approach/departure infrastructure requirements, are seen as a means of reducing airport congestion by diverting short-haul trips to an independent airport system. The Vertiport would offer passengers and carriers the convenience of a decentralized system in a multi-point, short-haul air transportation network. The Civil Tilt Rotor (CTR) is a VTOL aircraft that combines the merits of the helicopter with those of the conventional turboprop aircraft, providing fast, smooth, and quiet cruise conditions.

This study is developing planning criteria for a CTR/Vertiport air service suited to Canadian needs. The work will describe the development of the tilt-rotor aircraft, outline its capacity for enhancing the air transportation system in Canada, and assess its market potential.

Contractor: Airport Planning Associates Inc., Montreal, Quebec
Report: None to date
Schedule: August 1989 - April 1991
Funding:

TDC	$125 000
Energy R&D Program	$100 000
Total	$225 000

Project Numbers: 7301, 7303, 7476, 7695
File Number: 1455-210
Project Officer: Barry B. Myers



HIGHWAY TRANSPORTATION

HIGHWAY TRANSPORTATION

The highway system serves as Canada's primary mode of transportation for most goods and people in all but a few specialized markets. For the 1990s and beyond, the system will continue to be a key factor in supporting and promoting interprovincial and international trade and tourism, and in maintaining the high level of personal mobility that Canadians have come to expect. Because no single agency is responsible for all facets of highway transportation, all levels of government and industry must cooperate if new technologies are to be successfully adapted to this mode.

Highway Operations

The most dramatic improvements in highway efficiency and productivity are expected to come from the application of electronics to highway transportation. In the future, computers, communications, and other electronic technologies will be integrated to generate an "electronic highway" that links driver, vehicle, and roadway in a system that can provide any combination of traffic control, fleet management, navigation, and driver advisory functions. TDC is involved in several aspects of this emerging domain. One project provided an overview that is to be used as the basis for a long-term development program, and another involved the application of an expert decision-making system to vehicle dispatching. In addition, researchers are testing prototypes of a vehicle-mounted electronic log book.

One aspect of TDC's work in improving highway operations stems from Transport Canada's responsibility for the transportation of hazardous products. TDC works closely with the Transport Dangerous Goods Directorate to identify projects to be undertaken on its behalf. Work in progress includes the development of an expert system to interpret dangerous goods regulations.

Infrastructure

Planners estimate that additional expenditures of at least a billion dollars a year over the next ten years are needed to improve the national highway system. Given the limited resources available, TDC's selective program of research in highway infrastructure is designed to ensure the cost-effectiveness of improvements to this system. In addition, TDC participates in the Canadian Strategic Highway Research Program, which addresses the problems of maintenance and rehabilitation of Canada's highway system.

Demands for greater productivity in the trucking industry, safer highways, and preservation of the country's infrastructure require better industry control of vehicle loadings, improved understanding of highway use, and better administration of existing laws and regulations.

A major thrust for TDC's highway projects is the application of technology to improve the monitoring of compliance with regulatory requirements and to facilitate the management of heavy vehicles. Using test sites in British Columbia, TDC will participate in the U.S. Heavy Vehicle Electronic License Plate program by assessing the improvements possible in heavy vehicle management through the use of automatic vehicle identification, weigh-in-motion, and classification technologies. The combination of these technologies will permit better road use data to be collected with less effort. It will also allow trucks to by-pass weigh stations and points if the truck is in compliance with the various regulations, and may permit communication to and from the truck.

The development of on-board truck scales, a parallel project, will allow the truck operator to maximize payload while remaining within legal limits.

HIGHWAY TRANSPORTATION

Heavy Vehicle Safety

Safety is Transport Canada's first priority. TDC's focus on heavy vehicles responds to the increasing role of highway freight transport in Canada's economy and the mounting concern over how this will affect safety.

One major project, an operational demonstration of an antilock braking system (ABS) on fuel tankers, is a cooperative effort complementing U.S. work by the National Highway Traffic Safety Administration. The B-train tractor double trailer configuration chosen for testing in Canada provides an excellent test case for ABS technology.

Bus Technology

Research on intercity bus transportation, the most economical and energy-efficient form of intercity travel, has been a major component of TDC's program over the last decade. Bus manufacturing is an important Canadian industry and significant economic and regional development spin-off benefits are expected from this research.

TDC's principal initiatives in the development of new bus technology have culminated in a new generation of intercity buses either close to production or already in service. Two major operational demonstrations are continuing under the Canada-Quebec Economic and Regional Development Agreement and accessible transportation programs. The demonstration of twelve Prévost articulated intercity buses on Voyageur's Montreal-Quebec City route has entered its second year. The project has clearly demonstrated the suitability of the new high-capacity design for line-haul service. A long-term demonstration of a fully integrated accessible bus service is being undertaken by Canada Coach Lines, on behalf of the Canadian Bus Association, to measure the demand for such a service and to investigate the operational issues involved. This project is described in the chapter on Accessible Transportation.

The extra-long intercity bus developed by Motor Coach Industries will offer significant improvements in passenger comfort, productivity, and accessibility. Since present regulations do not permit such buses to operate on the roadway, demonstrations to interest groups are under way to establish that a 45-foot bus can operate safely and does not adversely affect other traffic.

Truck Technology

TDC's truck technology projects focus primarily on safety, usually combined with a secondary objective, such as higher productivity or reduced damage to the highway infrastructure. Current work includes a study of improved liftable axles, which are designed to reduce pavement damage and improve vehicle handling and stability while maintaining the allowable payload; an investigation of the traction characteristics of varied logging truck configurations; and the development of a lighter salt spreader that should decrease the road damage caused by winter operations.

Energy Conservation and Alternative Fuels

The multi-departmental Energy Research and Development Program provides funding for projects primarily aimed at reducing the use of petroleum fuel, either directly through improved fuel efficiency or indirectly through the use of alternative fuels. Projects on heavy vehicle fuel consumption include tribology research to improve the understanding of energy losses in engines and drive-trains, and the development of a computer simulation model that can optimize fuel consumption by correlating the effects of the complex interactions between driver, vehicle, road, and environment on energy efficiency.

Research into fuel use is expected to be increasingly directed at problems of environmental degradation caused by vehicle emissions. Current projects are investigating technologies to reduce the pollution caused by the burning of diesel and methanol fuels in truck and bus engines.

Transit and Traffic Technologies

TDC's focus in transit and traffic technologies is on the improvement of traffic management and transit information systems in urban areas. One project, designed to reduce traffic congestion and energy consumption, is testing a microcomputer-based traffic engineering system. Another is employing computerized voice-based technology to develop a system that will allow users ready access to information about public transit.

An overview of highway vehicle electronic technologies

This project, undertaken with the Ministry of Transportation of Ontario, produced an extensive report on the complementary technologies of automatic fleet monitoring, vehicular monitoring/control, and travel support systems, and presented an update on navigation systems.

The study is an essential step in establishing a Canadian long-term program in road vehicle electronics, an issue of particular importance to the trucking industry. Free trade with the United States has placed pressure on the Canadian trucking industry: Canadians must compete with U.S. manufacturers despite the generally longer distances in Canada for the transport of raw materials and the shipment of finished goods.

The study concluded that vehicle electronic systems promise increased efficiency through better fleet use and more efficient vehicles and drivers. They could also reduce highway deaths and injuries through the monitoring of vehicle and driver performance.

Contractor: Parviainen & Associates, Oakville, Ontario

Report: *(Draft)* TP 10473E, An overview of available and developing highway vehicle electronic technologies, Parviainen & Associates, 1990

Schedule: February 1989 - March 1990

Funding:

TDC	$105 000
Ministry of Transportation of Ontario (in-kind)	$10 000
Total	$115 000

Project Number: 7207

File Number: 1465-529

Project Officer: Lewis Sabounghi

Vehicle electronics offer potential for increased highway safety by focussing the driver's attention on the road.

Knowledge-based vehicle dispatcher's assistant

Optimal routing and scheduling is vital to commercial road operations. Dispatchers must consider many factors, including distance, safety, and customer requirements. An expert system would help to improve safety and to reduce the time, fuel, and human costs involved in surface transportation, while maintaining consistent dispatching performance. Potential customers for such a system include commercial and public road operations and emergency response systems.

This project's goal was to develop a computer-assisted scheduling system that could free human dispatchers from low-level decision-making. Researchers studied the application of an expert system to the dispatching of orders from Canadian Liquid Air Ltd.'s plant in Hamilton to its widely dispersed clientele throughout Ontario.

A demonstration of the contractor's prototype system at Canadian Liquid Air was well received by dispatching staff and management, indicating that a rule-based expert system is effective in implementing basic dispatching functions. Considerable interest in the prototype has been expressed by the artificial intelligence research community in Canada.

Contractor: Applied AI Systems Inc., Kanata, Ontario
Report: TP 10414E, Knowledge-based dispatcher's assistant, Applied AI Systems, 1990
Schedule: August 1987 - June 1990
Funding:

Energy R&D Program	$99 526
Supply and Services Canada	$57 000
Total	$156 526

Project Numbers: 6900, 6901
File Number: 1465-509
Project Officer: Lewis Sabounghi

An expert system could free dispatchers from low-level decision-making.

Electronic log book

This project is developing an on-board data acquisition system that will record important information about vehicles, such as speed and rpm. The integrated log book responds to both Canadian and United States requirements for recording hours of service.

Centrodyne Inc. is developing a second generation of an on-board computer it originally conceived to replace an electro-mechanical tachometer. In addition to recording trip data, the computer features a built-in log book that provides visual displays of hours of service data as well as hard-copy logs. Data acquired by the vehicle-mounted unit can be transferred directly, or via a portable data transfer unit, to an off-line computer programmed to produce hard-copy trip reports. The vehicle-mounted unit may be installed with or without displays and push buttons, allowing for both active and passive systems.

Aside from the particular benefits of electronic systems, such as accuracy, reliability, ease of maintenance, and light weight, the on-board computer provides digital displays and alarms unavailable in other systems, as well as protected areas of memory for recording accident data.

Funded under the Canada-Quebec Economic and Regional Development Agreement, the project comprises two phases: a conceptual study was followed by the development of specifications and the production of prototypes, which are currently being tested.

Contractor: Centrodyne Inc., St. Laurent, Quebec
Report: None to date
Schedule: March 1989 - February 1991
Funding:

Centrodyne Inc.	$500 000
Ministère des Transports du Québec	$154 500
TDC	$154 500
Total	$809 000

Project Number: 7310
File Number: 1465-530
Project Officer: Lewis Sabounghi

Electronic trip recorder with integrated electronic log book

Dangerous goods advisor

The regulations dealing with the transportation of dangerous goods in Canada and around the world are complex and often difficult for private industry to apply effectively and consistently. To help the Transport Dangerous Goods Directorate of Transport Canada to respond to requests for the interpretation and application of dangerous goods regulations, TDC undertook the development of a prototype of an expert system to clarify rulings and to provide advice on placarding, classification, exemptions, and documentation required by handlers, carriers, or manufacturers.

The proposed system was to provide relatively unskilled persons with quick resolutions to complex problems by selecting an interpretation from a computer data base incorporating the knowledge and judgment of many experts.

A demonstration version of the prototype was completed and evaluated. The project showed that the task of providing an expert system to interpret dangerous goods regulations is far more difficult than originally anticipated. However, the evaluation provided useful data on the development of such a system. Interest expressed by the Canadian Chemical Producers Association has led to consultations between government and industry representatives concerning further application of this work.

Contractors: Northern Dynamics Ltd., Toronto, Ontario; Ogilvie Consulting, Toronto, Ontario; and MaSyCom Consultants, Montreal, Quebec
Report: Non-releasable, contains proprietary commercial information
Schedule: January 1989 – October 1990
Funding:

TDC	$119 000
Surface Group	$100 000
Total	$219 000

Project Numbers:
7152, 7153, 7154, 7500, 7501, 7502
File Number: 1465-534-2
Project Officer: Wayne G. Rowan

Canadian Strategic Highway Research Program

The Canadian Strategic Highway Research Program (C-SHRP) was launched in 1987 to participate in a parallel U.S. program, SHRP, and to conduct complementary research. The $5-million program, jointly funded by the federal, provincial, and territorial governments, shares the objective of the U.S. initiative – stimulating the development of highway construction and maintenance technology. TDC takes part in C-SHRP through membership on the steering committee for administration and technical control.

Canada is represented on SHRP advisory committees and expert task groups, and provincial highway agencies are participating in its Long Term Pavement Performance program. Forty-four test sites have been established across Canada to evaluate different types of pavement construction under a variety of environmental and traffic conditions.

The complementary research program is evaluating the performance and cost-effectiveness of maintenance treatments and rehabilitation techniques for the aging Canadian highway system. Work includes studies on pavement performance, an assessment of the relative performance of different strategies for roads treated with bitumen, and an evaluation of alternative maintenance procedures for surface defects in flexible pavements.

The second half of the C-SHRP program will emphasize technology transfer. A plan of action will be defined to ensure that the technical results of SHRP and C-SHRP are widely disseminated and implemented.

Contractor: Transportation Association of Canada, Ottawa, Ontario

Reports: *(Draft)* TP 10392E, TP 9759E, TP 9220E, Canadian Strategic Highway Program: progress reports, Transportation Association of Canada, 1989/90, 1988/89, 1987/88

Schedule: April 1987 - March 1994

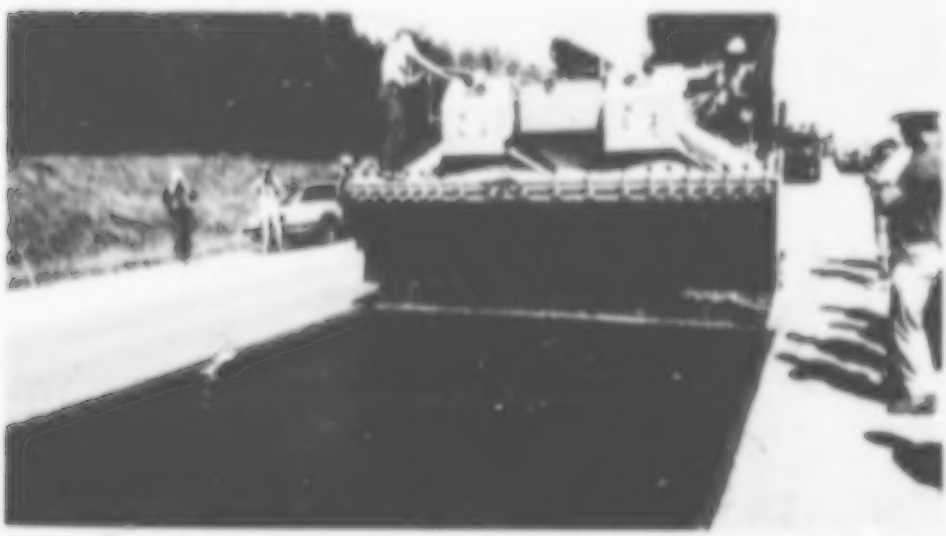
Funding:

Provinces and territories	$4 500 000
TDC	$500 000
Total	$5 000 000

Project Numbers: 7053, 7057

File Number: 1450-154

Project Officers: Doug W. Dibble, Brian Marshall



Chip seal being applied to a section of highway as part of C-SHRP testing program

Heavy vehicle identification system

Enforcement of heavy vehicle regulations is costly, time consuming, and difficult to apply consistently, straining the resources of regulatory agencies, vehicle owners, and shippers. Automation of enforcement would improve safety and decrease expenses.

This project will provide a major demonstration of a heavy vehicle management system integrating electronic licence plate (HELP) technology for automatic vehicle identification and classification with weigh-in-motion and communication technologies. This system has considerable potential in the efficient management of the trucking industry. It not only facilitates the enforcement of regulations and the protection of the highway, but also allows trucks to be cleared electronically. Those complying with regulations can then bypass the weigh station, thus saving energy, cutting costs, and reducing the pollution caused by idling at the station. Transportation agencies could also realize savings through the automation of data collection on heavy vehicles and the monitoring of the movements of hazardous materials.

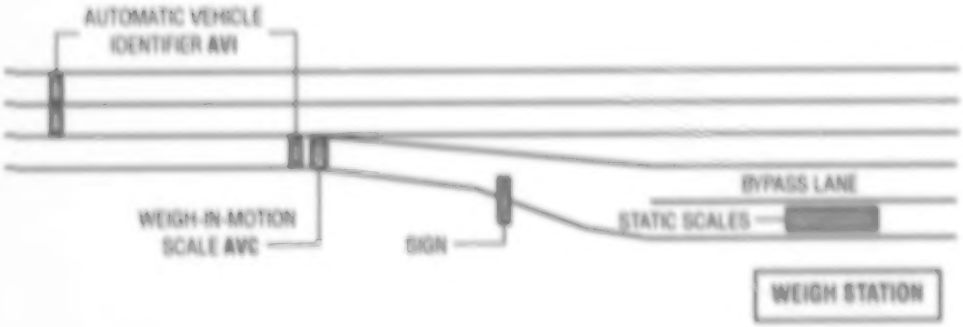
Software and hardware interfaces are being developed to integrate current Canadian weigh-in-motion and automatic vehicle identification technologies. The system design ensures that the required data will be collected and appropriate messages generated for truck drivers and highway authorities. The system is compatible with and complementary to the CRESCENT demonstration project in the United States.

Installed at two sites in British Columbia, the HELP system will be assessed over a 12-month period. In addition, the contractor will produce an operating and maintenance manual and train highway personnel in the operation of the system.

Contractor: Status Electrical Corporation, Abbotsford, B.C.
Report: None to date
Schedule: July 1990 - September 1991
Funding:

TDC	$638 952	
Energy R&D Program	$350 000	
Ministries of Transportation and Highways and of the Solicitor General of British Columbia	$210 000	(in-kind)
Total	$1 198 952	

Project Numbers: 7288, 7289, 7354, 7359, 7360
File Number: 1455-537
Project Officer: Lewis Sabourin



Laidlaw, B.C., site configuration. Vehicle can bypass the weigh station, saving time and energy.

On-board weigh scale

Accurate and reliable weight information can be a considerable advantage to truckers, who are liable to receive an overweight ticket if even one axle of the vehicle is carrying more than the maximum weight allowed. After a review of various candidate technologies, this project developed an on-board sensor capable of determining the weight carried by an individual truck axle.

The advantages of this new technology over earlier on-board weigh systems are lower costs for installation, calibration, and maintenance, which should ensure the acceptance of the system by potential users. Previously the load cells had to be mounted between the truck's frame and suspension. The new system, which measures shear stress, not weight, is welded directly onto the axles and the frame of the truck and requires no modification of the suspension or any truck components. The load cell, inserted in a piece of steel, sends an electric charge through the metal and the instrument measures the change in electricity due to shear stress. This data is then relayed to a microprocessor in the truck cab, which analyses and displays the results. The display indicates to the driver the individual axle and gross vehicle weights.

An important benefit of this work is the potential for reduced numbers of overweight vehicles on the road and therefore less damage to the road network. The contractor expects early acceptance of this technology in Canada and plans to export the system internationally.

Contractor: International Road Dynamics Inc., Saskatoon, Saskatchewan
Report: None to date
Schedule: March 1989 – July 1990
Funding:

Supply and Services Canada	$209 040
TDC	$100 000
Ministry of Transportation of Ontario (in-kind)	$20 000
Total	$329 040

Project Numbers: 7200, 7201
File Number: 1455-536
Project Officer: Lewis Sakoungh

On-board weigh scale can display individual axle and gross vehicle weights.

Evaluation of antilock braking systems

Studies have indicated that braking performance is an important contributing factor in heavy truck accidents, and that antilock braking systems (ABS) are the most promising technical improvements to date. ABS allows the driver to maintain vehicle stability while increasing braking. However, the trucking industry seems reluctant to adopt this technology, because the long-term operational performance of ABS is unknown. Earlier TDC-sponsored work has shown that ABS inhibits tractor jackknife and trailer swing, but no effective method has been found to detect the onset of jackknife or to prevent or control it under all conditions. The challenge is to design a brake system suited to a wide range of tractor-trailer configurations, loading conditions, and road surfaces. TDC is exploring ABS's capacity to meet this challenge.

The first phase of this project includes track testing to establish vehicle performance and the requirements for installation of ABS. The second phase, an in-service evaluation of long-term performance to be conducted in the Toronto and Montreal areas, will last for at least one year. Working with fleet operators, such as Shell Canada and Canadian Liquid Air Ltd., and ABS manufacturers, the performance, reliability, and durability of ABS technology will be tested on B-train double tanker vehicles.

ABS is being installed on both tractors and trailers for ten of a control fleet of twenty vehicles. The data collection will be compatible with that of a U.S. National Highway Traffic Safety Administration study, which is monitoring 17 truck fleets in six locations to evaluate ABS equipment from five manufacturers.

Track tests are under way using a Shell vehicle and a Bosch ABS. A prototype on-board monitoring system has already been selected, and specifications for the instrumentation of Canadian Liquid Air vehicles are being drawn up.

Contractors: Shell Canada, Calgary, Alberta; Canadian Liquid Air Ltd., Montreal, Quebec; and others to be determined
Report: None to date
Schedule: January 1988 - December 1992
Funding:

TDC		$525 000
Industry (in-kind)	approx.	$380 000
Ministry of Transportation of Ontario		$305 000
Surface Group		$90 000
Total	approx.	$1 300 000

Project Numbers: 7616, 7619, 7668, 7717
File Number: 1465-543
Project Officer: Sesto Vespa

B-train double tanker vehicle, incorporating ABS technology, on test track in Centralia, Ontario

Anti-jackknifing systems for tractor semitrailers

Jackknifing of heavy articulated highway vehicles, such as tractor-trailer combinations, is a serious safety problem and the direct cause of significant property damage, personal injuries, and fatalities. The development of an effective anti-jackknifing device, acceptable to the trucking industry, presents a considerable technical challenge.

This study investigated the feasibility of using devices to control tractor jackknifing and trailer swing in tractor semitrailers. Using computer simulation, the researchers examined the characteristics of jackknifing and trailer swing, and potential methods of control through devices located about the fifth wheel. They found that the articulation angle in jackknifing diverges faster than it does in trailer swing, and in the opposite direction. Trailer swing proved to be a milder form of instability as the trailer tends to right itself without any form of compensation. The devices under review were categorized as locking, clamping, limiting, or a combination of these. All showed merit in controlling tractor jackknifing, but demonstrated little or no ability to control trailer swing. In fact, some devices made the problem worse, because of the large torques produced during trailer swing. When trailer swing was inhibited by a restraining torque, the rear tractor tires became saturated and the entire vehicle rotated out of control. Thus research focussed on tractor jackknifing control only.

This work showed that proper distribution of available braking forces significantly reduces the severity of jackknifing, and that brake proportioning based on loading is crucial. It also demonstrated that the difference between the peak and sliding friction coefficients of friction surfaces, not the magnitude of the coefficients, determines the severity of the resulting jackknifing.

Contractor: TES Ltd., Ottawa, Ontario
Report: TP 10474E, Development of an anti-jackknifing system for tractor semitrailers: feasibility study, phase 1, stage 2, TES Ltd., 1990
Schedule: October 1988 - March 1990
Funding:

TDC	$94 463
Supply and Services Canada	$45 000
Total	$139 463

Project Numbers: 7150, 7151
File Number: 1465-535
Project Officer: Savio Vespa

The results of a jackknifing accident

Tanker stability

With the relaxation of regulations governing vehicle weights and dimensions, sloshing in liquid trailers has become a serious problem. Prior to this study, little was known about the stability of large, partially filled tankers under various manoeuvring conditions at different speeds. This project investigated the handling, stability, and control characteristics of various tank-vehicle combinations through systematic computer simulations and field testing.

Researchers developed simulation programs to investigate the rollover threshold, transient directional response, and handling and stability characteristics of tank vehicle combinations as a function of cargo load, fill level, vehicle configuration, tank design, and vehicle manoeuvre.

A series of field tests by the Ontario Ministry of Transportation, in collaboration with the CONCAVE Research Centre of Concordia University, employed a specially constructed and instrumented tank-truck. Video cameras observed vehicle response during manoeuvres such as lane change, deceleration, and braking in a turn.

Computer simulation results for various fill conditions, speeds, and manoeuvres correlated well with field test results. The research indicates that while compartmented tanks increase the stability of partially filled vehicles, modified oval and square tanks exhibit higher overturning limits when carrying lighter liquids, and circular tanks show better stability for denser liquids.

Contractor: Seshadri Sankar Inc., Brossard, Quebec

Report: *(Draft)* TP 10690E, Liquid tanker stability, Seshadri Sankar Inc. and CONCAVE Research Centre, 1990

Schedule: June 1985 - September 1990

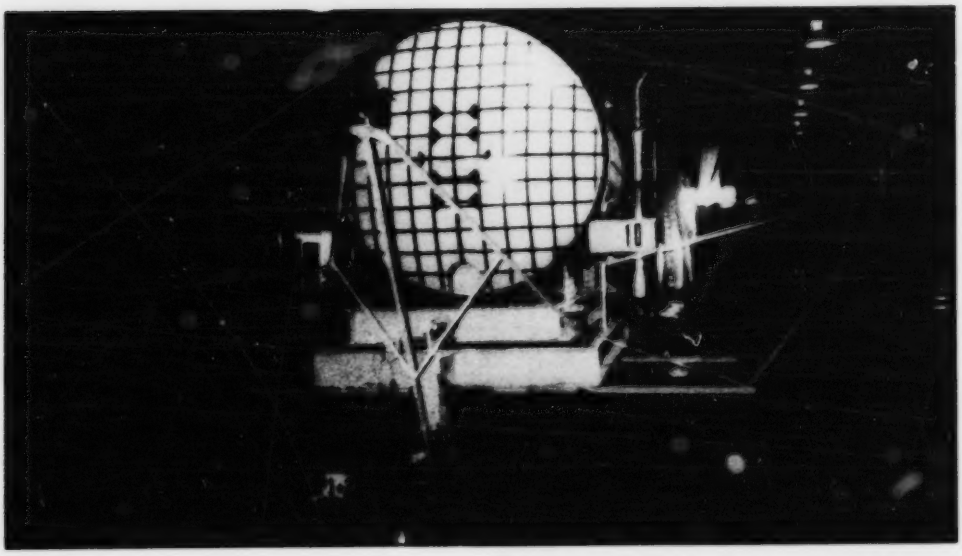
Funding:

Energy R&D Program	$247 008
TDC	$41 055
Ministry of Transportation of Ontario + in-kind	$22 000
Total	$310 063

Project Numbers: 6407, 7395

File Number: 1465-421-4

Project Officer: Lewis Sabounghi



Vehicle used for field testing to verify model results

Vehicle dynamics expert system

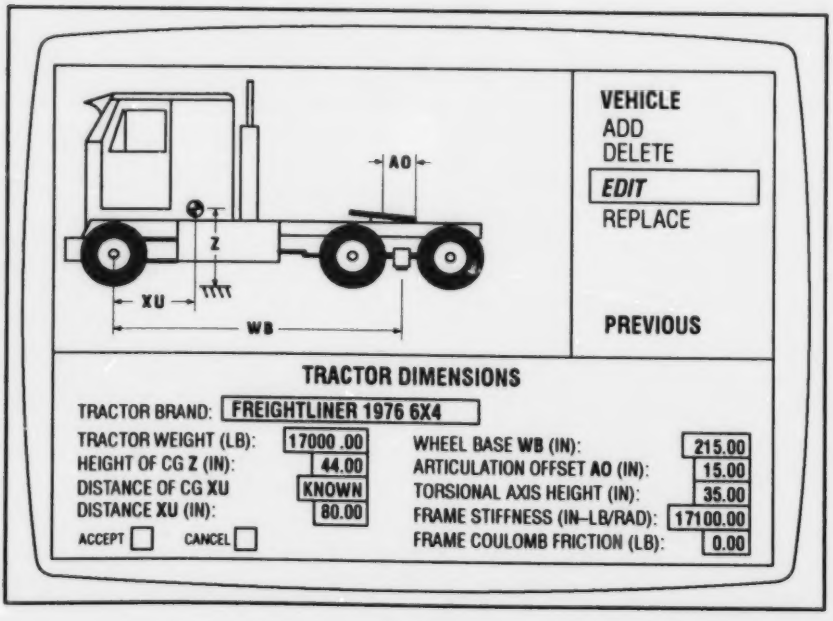
Vehicle dynamics currently plays only a small part in the overall design considerations for heavy vehicles. Since no single manufacturer produces both tractor and trailer units, vehicle combinations are rarely designed as a system. Research and development of modern highway heavy vehicles require complex and costly dynamic modelling and simulation at an early stage to reduce the cost of prototype development and to improve the performance of the final product.

The University of Michigan's Transportation Research Institute has developed software capable of comprehensive vehicle dynamics simulation permitting the prediction of rollover threshold, transient steering response, and braking performance of heavy vehicle combinations. Although this software has been used by Canadian and United States transport research organizations to simulate the dynamics of heavy vehicles, its complexity has limited its use.

This project is developing PC-based models that will retain the broad scope of the full-scale software, but will be much easier to use and will provide easily interpreted data. A comprehensive data base will be compiled on vehicle weights and dimensions, as well as on suspension and tire parameters. Expert system concepts will be developed and integrated to enhance and facilitate the simulation of heavy vehicle systems, and to permit comprehensive diagnosis of potential problems associated with their dynamic performance.

Consultations are being held with government and industry experts to define user needs. The project shows excellent potential for transfer of technology from the research community to the manufacturing sector.

Contractor: CIE-TECH Inc., Brossard, Quebec
Report: None to date
Schedule: January 1990 - June 1993
Funding: $444 121
Project Number: 7285
File Number: 1465-557
Project Officer: Sesto Vespa



Sketch of computer display of one set of dimensions available from the data base

Articulated intercity bus demonstration

This project is the culmination of a 10-year program of R&D on high-capacity intercity buses that began with a study of a European-made articulated bus followed by its testing on a Voyageur route. Although the bus proved unsuited to the Canadian environment, the test program generated interest in the production of a Canadian-made articulated bus. With the financial assistance of the federal and Quebec governments, Prévost Car Inc. of Ste-Claire, Quebec, developed a prototype of a technically advanced articulated bus, the Prévost H5-60, which is now in production.

A two-year demonstration of twelve of these buses, begun in November 1988 on Voyageur's Montreal-Quebec City route, is continuing under new owners, Autocars Orléans Express Inc. Partially funded under the Canada-Quebec Economic and Regional Development Agreement, this demonstration has two objectives – to showcase the new design and promote its use, and to demonstrate a new level of comfort and spaciousness in intercity bus service.

The articulated buses provide superior handling, a more comfortable ride, and improved ventilation. They feature antilock brakes, a tighter turning radius than regular buses, and more space for the driver. They can carry up to 72 passengers, but are being operated in a low-density configuration of one single and one double seat per row. This 48-seat arrangement provides 30 percent more leg and elbow room.

The success of the demonstration has indicated the value of the new high-capacity design, and much of the same technology is being incorporated into Prévost's newest 40-foot coach. The demonstration is also providing detailed technical, operational, and marketing information that will be made available to prospective operators.

Contractor: Autocars Orléans Express Inc., Montreal, Quebec

Report: TP 8826F, Rapport d'évaluation et d'épreuves d'endurance du prototype de l'autocar articulé H5-60 de Prévost Car, phase I, Voyageur Inc., 1987

Schedule: October 1987 - June 1991

Funding:

Voyageur Inc.	$5 180 000
Transport Canada	$1 749 000
Ministère des Transports du Québec	$1 749 000
Total	$8 678 000

Project Number: 6942

File Number: 1465-490-4

Project Officer: Brian Marshall

Prototype 45-foot intercity coach

A new coach developed by Motor Coach Industries (MCI) is the first North American 45-foot intercity bus to be designed and engineered as such, not merely as a stretched version of a standard 40-foot model. The coach features many unique engineering elements and provides complete accessibility for disabled and elderly travellers (see p. 129).

Development of the coach took place in three stages. The initial design stage focussed on accessibility, development of the suspension system, and airflow requirements. Designers experimented with new suspension simulation techniques developed by UTDC of Kingston, Ontario, in an earlier TDC project. Previous TDC-sponsored research also led to the development of an air-conditioning and heating system that provides the greatest possible ratio of fresh to re-circulated air.

In the second phase of the project, MCI modified a conventional 40-foot bus to test the subsystems developed specifically for this project, such as suspension and engine-cooling systems. They then finalized specifications for the larger bus. After completing the design of the vehicle, MCI built a prototype at its plant in Winnipeg, and unveiled the bus in May 1990.

Because the new coach exceeds the 40-foot limit in place in every Canadian province and in many U.S. states, demonstrations to government agencies are planned, with a view to gaining legislative acceptance. In addition, extensive market research and testing will determine the response of coach operators and the disabled community.

Contractor: Motor Coach Industries, Winnipeg, Manitoba

Report: None to date

Schedule: October 1987 - September 1990

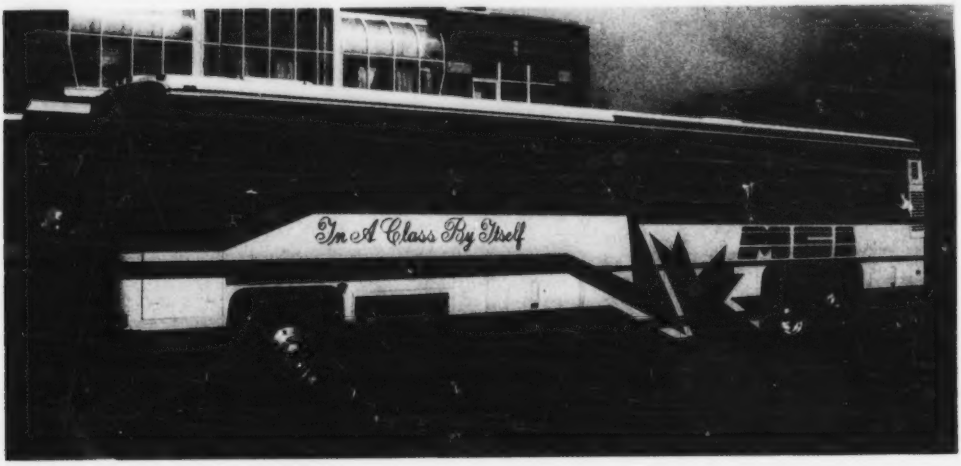
Funding:

Motor Coach Industries	(approx.)	$2 000 000
Supply and Services Canada		$473 633
Energy R&D Program		$240 000
TDPP		$145 500
TDC		$100 867
Total		$2 960 000

Project Number: 6978

File Number: 1465-472-3

Project Officer: Brian Marshall



Application of multiplexing technology

Multiplexing, the transmission of multiple electronic messages over a common link, permits a considerable reduction in the total wiring of a vehicle. This technology could greatly benefit the transportation industry, particularly since the electronics systems within its vehicles are becoming increasingly complex. While these electronic systems lead to better performance, they also create problems. In buses, for example, drawbacks include severe space constraints and more labour-intensive fabrication and installation. In addition to solving these problems, multiplexing offers higher reliability and lends itself to electronic diagnostics for preventive maintenance and repair.

While multiplexing has been adopted to some extent by the automotive industry, little application has yet been made to buses and trucks. This project investigated the technical and economic feasibility of applying multiplexing technology to intercity coaches, developed detailed requirements for implementation of a prototype multiplexing system, and recommended measures to ensure design integrity in the bus system. An assessment of current practices in automotive multiplexing and their application to buses was included.

Researchers found that this technology can be used to improve the reliability of the vehicle's electric components and demonstrated the feasibility and advantages of its use in buses.

Contractor: Manitoba Research Council, Winnipeg, Manitoba

Report: TP 10522E, Feasibility study of applying multiplexing technology to intercity coaches, Manitoba Research Council, 1990

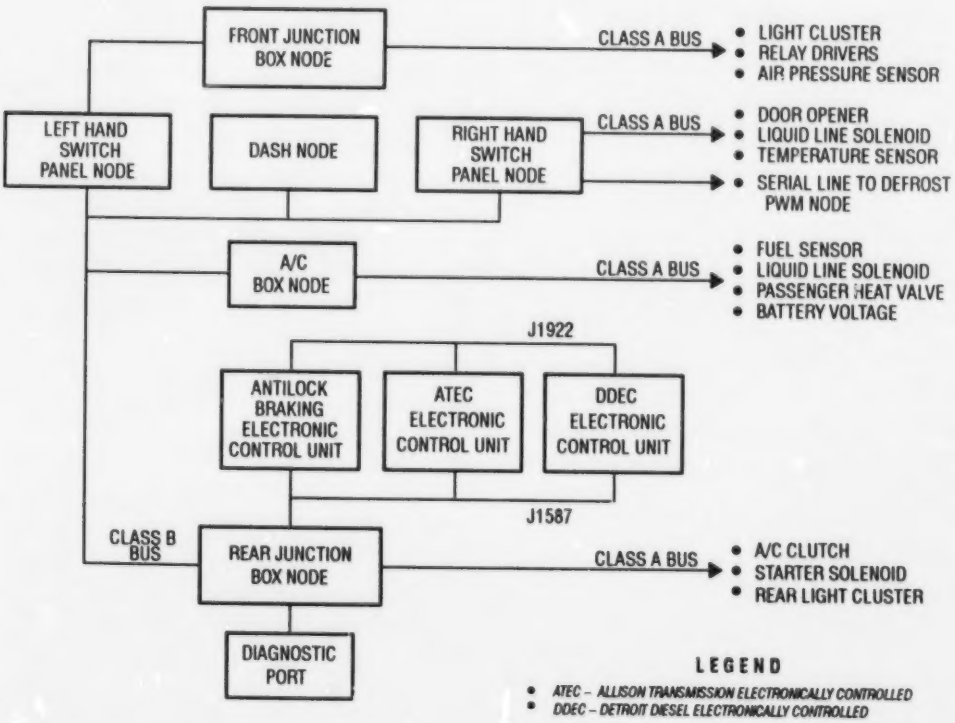
Schedule: September 1989 – June 1990

Funding: $48 667

Project Number: 7213

File Number: 1465-550

Project Officer: Lewis Sabounghi



Coach multiplexing system eliminates the main wiring harness.

Semitrailer liftable axles

The heavy vehicle fleets in Quebec and Ontario include several thousand semitrailers fitted with multiple axle units that permit the carriage of very heavy loads. In order to reduce the impact of these loads on the roadway and structures, multiple axles are spaced to avoid the concentration of loads transmitted to the ground. Almost all vehicles with widely spread axle groups are equipped with one or more liftable axles.

The 1986 Vehicle Weights and Dimensions Study conducted by the Transportation Association of Canada (formerly the Roads and Transportation Association of Canada) and the Canadian Conference of Motor Transport Administrators found that the liftable axle increases instability and its frequent misuse causes pavement damage. These would seem to be compelling reasons to ban the liftable axle. However, since a single liftable axle enables a semitrailer to add a payload of about 9 000 kg to the vehicle, it offers considerable economic benefits to industry.

This project, sponsored by TDC, the provinces of Quebec and Ontario, suspension and axle manufacturers, and several transport companies, will develop, test, and demonstrate improved liftable axles that incorporate lift and load control as well as steering features. The goal is to maintain the allowable lift axle payload while reducing pavement damage and improving vehicle handling and stability. Initially, performance standards will be developed for liftable axles. Researchers will evaluate the performance and durability of existing self-steering axles on a small fleet of tractor-semitrailers under normal Canadian operating conditions. The second phase of the project will develop and test lift and load control devices for liftable axles to regulate loads properly and to remove deployment control from the driver.

An economic impact study of the effects of liftable axles has been completed, and fleet testing of existing self-steering axles has been initiated and will continue for eighteen months. Currently, the project's technical working group is reviewing recommendations for performance and functional requirements.

Contractor: To be determined
Report: None to date
Schedule: May 1989 - December 1993
Funding:

TDC		$200 000
Industry	(in-kind)	$200 000
Ministry of Transportation of Ontario		$100 000
Ministère des Transports du Québec		$100 000
Total		$600 000

Project Number: 7278
File Number: 1465-547
Project Officer: Sesto Vespa

Tridem axle semi-trailer with air lift

Logging truck tridem axles

Log-hauling in the interior of British Columbia contributes an average of 30 percent to the cost of delivered wood. To minimize increases in transportation costs as timber resources become increasingly distant from the sawmills, truck operators have been attempting to augment the cargo capacity of their truck-trailer combinations by adding more axles to the trailers. However, increased capacity of the vehicle is offset by diminished traction, as well as reduced rollover threshold and directional stability.

The replacement of the conventional tandem axle by the tridem axle was proposed as a solution to this traction problem. Two basic configurations were considered: a tridem group consisting of a non-driven, lifting, steering axle with two driven axles, and a tridem group with all axles driven and non-lifting. Both concepts were rigorously analysed to determine whether acceptable performance could be achieved. Researchers developed computer-based models to predict the potential gain in net tractive effort and the dynamic stability of the overall vehicle configuration. This analysis enabled researchers to rank quantitatively any potential improvements in gradability and to consider all aspects of the problem of vehicle stability before construction began.

The analysis showed that traction/gradability would be significantly improved by using a tridem tractor unit. However, the vehicle dynamics study revealed performance deficiencies for some multi-articulation-point vehicles that use 3-axle tractors, and these deficiencies are carried over to the 4-axle tridem tractor. For a single-point articulated unit, the wide-track tridem tractor with an airlift axle in the pusher location offers the benefits of improved traction combined with the higher productivity currently available in multi-axle, multi-articulated configurations.

Contractor: Forest Engineering Research Institute of Canada (FERIC), Vancouver, B.C.

Report: *(Draft)* Development of a tridem axle tractor for log-hauling applications: phase I, FERIC, 1990

Schedule: September 1988 - May 1990

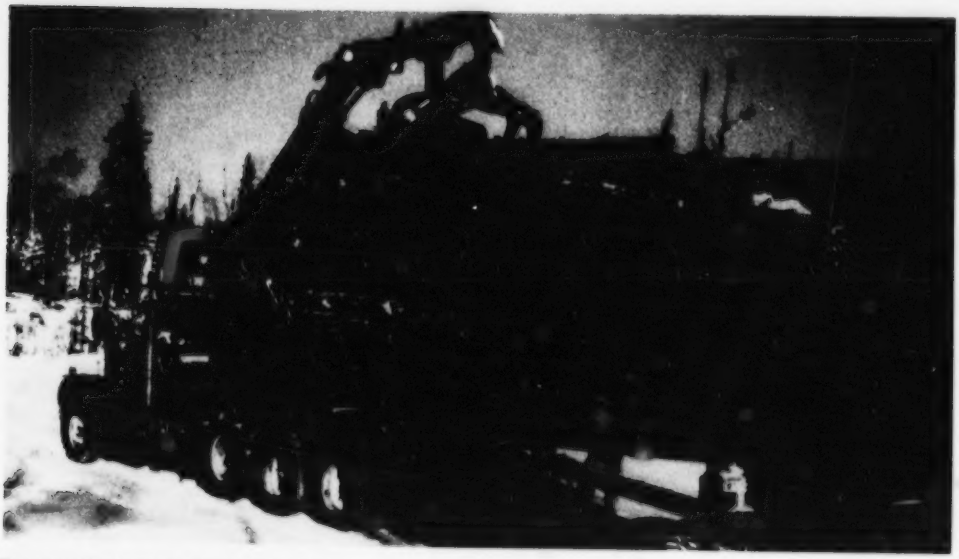
Funding:

TDC	$15 000
Supply and Services Canada	$75 000
Total	$90 000

Project Numbers: 7156, 7157

File Number: 1465-519-1

Project Officer: Sesto Vespa



Transporting logs in Western Canada

Reduced-weight salt spreader

Because they damage road surfaces, overweight vehicles are a major concern for provincial and municipal authorities. Quebec's ministry of transport has begun a program to progressively reduce the weight of its snow removal and multi-functional trucks, beginning with salt and abrasive spreaders.

This project involves the design, manufacturing, and testing of a salt and abrasive spreader at least a tonne lighter than current spreaders, which are 2.5 tonnes over the allowable 28 tonne maximum when loaded with sand. The design will also consider corrosion, conveyor wear, grille deformation, high centre of gravity, and improved operational safety through the use of new signalling accessories.

If successfully developed, this equipment would mean reduced acquisition and maintenance costs. Funded by the Economic and Regional Development Agreement (ERDA) between the federal government and the province of Quebec, the project responds to ERDA's mandate to strengthen the transportation equipment manufacturing sector in Quebec through research and development aimed at bringing new products to market.

Contractor: Société G.I.D. Design Ltée, Ste-Foy, Quebec
Report: None to date
Schedule: October 1989 - March 1991
Funding:

TDC	$194 713
Ministère des Transports du Québec	$194 713
Total	$389 426

Project Number: 7429
File Number: 1465-563
Project Officer: Sesto Vespa

Prototype reduced-weight salt and abrasive spreader using composite materials

Fuel consumption of heavy vehicles

More efficient use of energy would mean substantial savings for resource-based industries that rely on long-distance road transportation. A multi-year study of the factors influencing the energy consumption of heavy road vehicles has resulted in a first attempt at a universal heavy vehicle fuel consumption model grouping these factors into a system relating driver, vehicle, road, and environment. These relationships are affected by energy transformation in the engine, energy transmission to the wheels, energy balance between tires and road, complex movement of articulated vehicles, and the driver's technique. Comparisons of fuel consumption were based on a variety of cases: differences in drivers' techniques; different combinations of the semitrailer undercarriage; and different road surfaces and profiles.

Conducted by the Forest Engineering Research Institute of Canada, the project has resulted in a better understanding of the driver's role in the rate of energy consumption, and of the effects on driving performance of the road, vehicle, and environment interaction.

One forestry company is now using the model to assign tasks to its drivers. A follow-on project has begun to refine and calibrate the heavy vehicle fuel consumption model using the data collected, and a series of seminars is planned to explain the technology to interested groups.

Contractor: Forest Engineering Research Institute of Canada (FERIC), Pointe-Claire, Quebec

Report: TP 10081E, Energy consumption of heavy road vehicles: field parameter measurements and cross impact analysis (summary), FERIC, 1989

Schedule: December 1985 - November 1989

Funding:

Forest Engineering Research Institute of Canada	$1 000 000
Energy R&D Program	$275 000
Association du camionnage du Québec	$ 5 000
Total	$1 280 000

Project Numbers: 6593, 6594

File Number: 1465-470

Project Officer: Lewis Sabounghi

Vehicle used in field research on factors influencing fuel consumption

Study of truck drive train lubricants

In 1987 private and for-hire trucks used over three billion litres of fuel. A decrease of even a small percentage in fuel consumption by this sector would mean significant energy savings. In this study, researchers are examining the interaction of gear oil properties, energy consumption, and driveline durability. Testing of two types of lubricants – mineral and synthetic – covers the entire lubricant temperature range (-25°C to +120°C) expected in various operating environments in Canada.

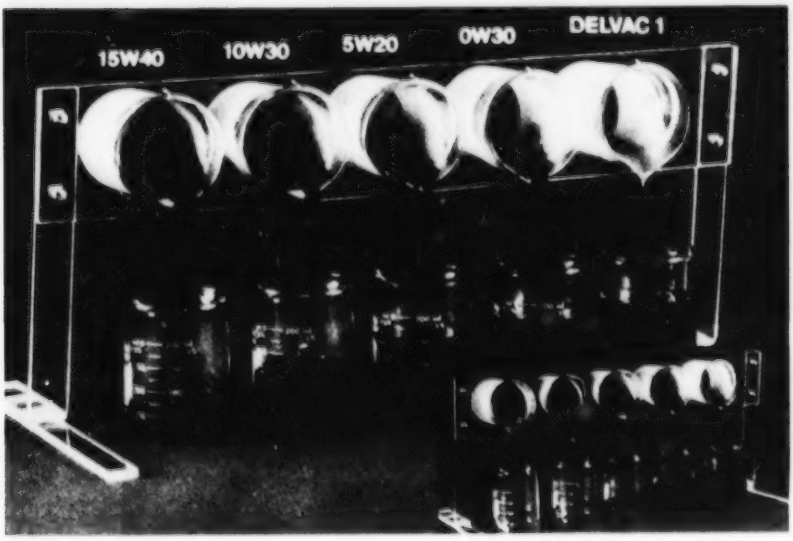
A tractor semitrailer combination was first instrumented and road tested. Several test lubricants were formulated using commercially available basic oils and additives. All-weather chassis dynamometer tests using two of the selected oils were carried out and the data were analysed in terms of relative fuel consumption, lubricant temperature profiles, gear speeds, and load factors. After further field testing, researchers were able to optimize the viscometric properties of the gear lubricant using commercially available additives and base stock components.

While field testing and refinement of the selected lubricants continue, the work to date has already demonstrated that significant reductions in fuel consumption are possible.

Contractor: Imperial Oil Ltd., Sarnia, Ontario
Report: None to date
Schedule: April 1987 - August 1991
Funding:

Energy R&D Program	$389 436
Forest Engineering Research Institute of Canada	$300 000
Imperial Oil Ltd.	$300 000
Supply and Services Canada	$200 000
Total	$1 189 436

Project Numbers: 6883, 6884
File Number: 1465-504
Project Officer: Lewis Sabounghi



Variations in viscosity of oils

Ker-Train bus transmission

Under earlier TDC contracts, Ker-Train Systems Ltd. designed and built a 64-speed, incrementally variable, computer-controlled transmission and tested it in a Marathon C-360 electric vehicle. The results were integrated and analysed in a modelling study for urban bus application that indicated fuel savings of about 25 percent could be realized by the installation of such a transmission, and that particulate emissions could be significantly reduced by avoiding those areas on the torque curve where such emissions were at a maximum.

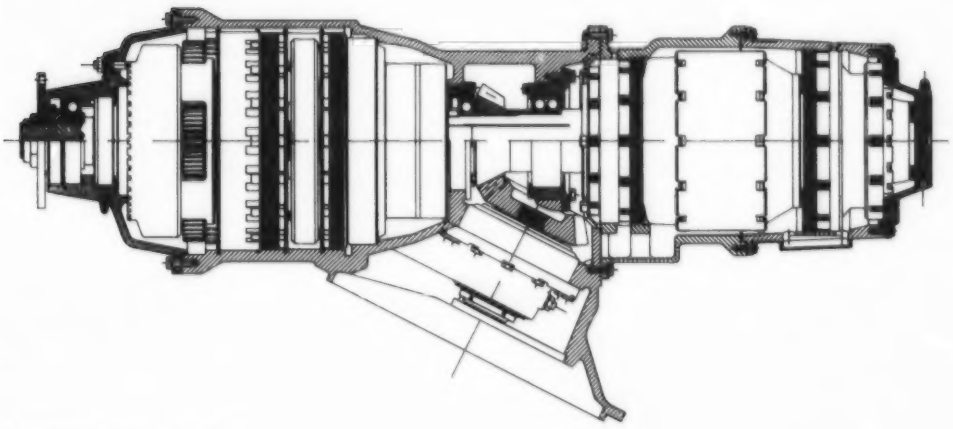
The advantage of the new transmission lies in the increased choice of ratios, which permits the engine to be maintained at a speed and torque corresponding to the lowest possible fuel consumption and with minimal emissions. It is considerably more effective than a conventional transmission at low speeds and when accelerating from a stop.

In this project, Ker-Train is designing, manufacturing, and testing a prototype suitable for installation in a transit bus. Following this work, the Ministry of Transportation of Ontario will sponsor installation and evaluation of the transmission in a Toronto Transit Commission bus, to determine whether the fuel economy and emission reduction reach predicted levels.

Contractor: Ker-Train Systems Limited, Kingston, Ontario
Report: None to date
Schedule: April 1987 - December 1990
Funding:

Energy R&D Program	$200 000
TDC	$113 125
Total	$313 125

Project Numbers: 6871, 6872
File Number: 1465-507
Project Officer: Roy S. Nishizaki



Ker-train bus transmission

NO_x emission reduction

The Raprenox system, discovered and patented by Dr. Robert Perry through his research at Sandia Laboratories, may offer a practical and effective method to reduce nitric oxides (NO_x) in diesel exhaust without affecting engine performance. The system injects into the exhaust product a gas that is generated from cyanuric acid, a cheap and readily available chemical. This acid can selectively and rapidly reduce nitric oxides in diesel exhaust.

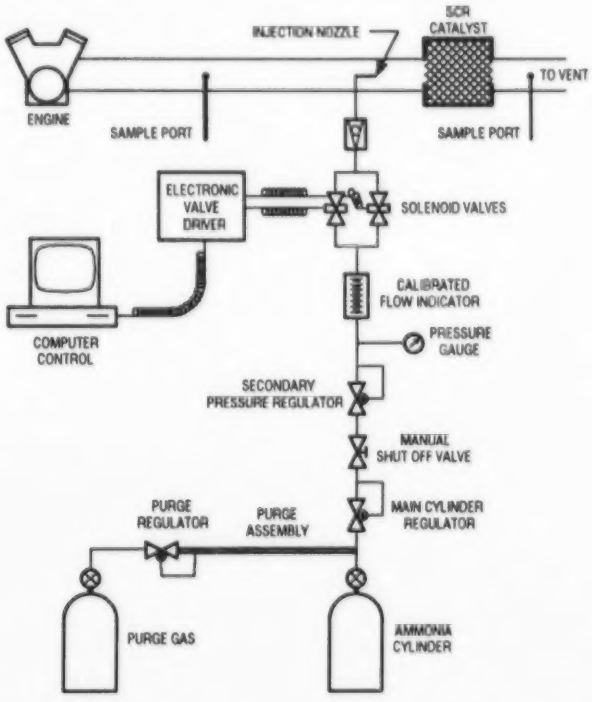
In this project, researchers are evaluating the extent of the system's ability to reduce NO_x emissions from diesel engines operating on either diesel fuel or natural gas, and comparing its effectiveness with that of ammonia injection into the exhaust stream.

To date, researchers have reviewed the literature and other sources on selective catalytic reduction systems involving ammonia. An ammonia injection system has been designed and a bench set-up assembled. Initially, the Raprenox system was to use powdered cyanuric acid, but researchers have since concluded that the liquid acid should be used. With this change, the Raprenox system will not be ready for testing until the spring of 1991.

Contractor: ORTECH International, Mississauga, Ontario
Report: None to date
Schedule: June 1989 - January 1991
Funding:

TDC	$401 800
Energy R&D Program	$200 000
Total	$601 800

Project Numbers: 7228, 7230, 7231
File Number: 1465-544
Project Officer: Roy S. Nishizaki



Ammonia/selective catalytic reduction injection system

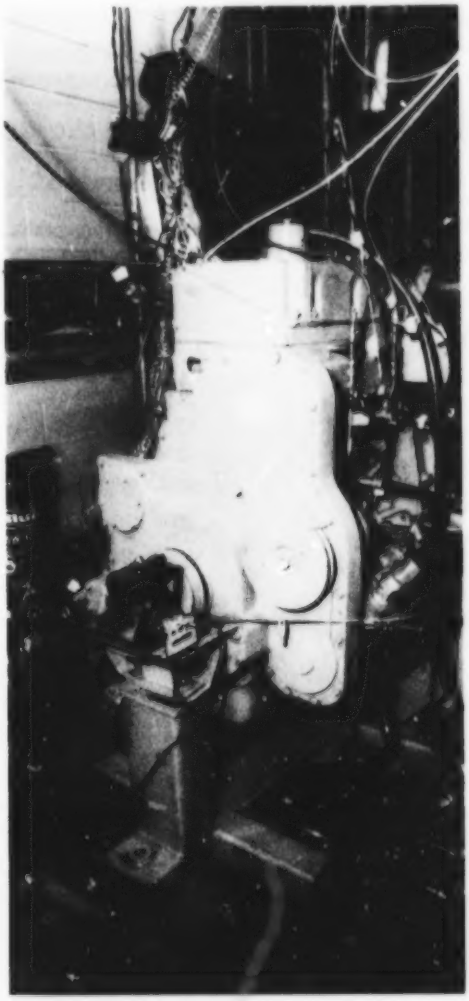
Diesel engine performance using neat methanol and glow plug ignition

Methanol is considered a viable alternative to diesel fuel in heavy duty engines because its combustion characteristics result in very low particulate matter in the exhaust gas. Both the proposed stringent regulations restricting emissions and the lack of a cost-effective particulate emission control technology for diesel engines make it an attractive choice. However, its low cetane number means that neat (100%) methanol cannot reliably be compression ignited in unmodified diesel engines under transient operating conditions. Combustion, under these conditions, is only possible through either additives to the fuel (cetane improver) or engine modification, which may include an ignition source or internal exhaust gas retainment for high compression temperatures.

In this project researchers are determining the best combination of piston configuration, injector spray pattern, and glow plug placement, through a series of tests on a single-cylinder Cummins L10 engine operating on methanol fuel. These tests involve one or two camshaft configurations each with three different injectors using individual, optimized timing settings. They will be run for two head and three piston configurations; piston selection depends on the injector configuration. Tests will then be run on a six-cylinder L10 engine.

Performance and emissions data collected at various loads and rotational speeds on the single cylinder laboratory engine have already led to the following findings: brake efficiency increases with loading, but levels off above medium loads; formaldehyde and unburned hydrocarbon emission concentrations vary inversely with engine load, while concentrations of nitrogen oxides vary with engine load; and advances in injection timing significantly reduce unburned hydrocarbon emissions, but significantly increase the emissions of nitrogen oxides. These findings correlate closely with published test results from full-size neat methanol multi-cylinder engines.

Contractor: Ortech International, Mississauga, Ontario
Report: None to date
Schedule: July 1989 - December 1991
Funding: Energy R&D Program $434 218
Project Number: 7287
File Number: 1465-559
Project Officer: Roy S. Nishizaki



Cummins single-cylinder L10 research engine

Acoustic emission testing of natural gas vehicle cylinders

Widespread commercialization of the use of natural gas fuel for vehicles faces two obstacles: the lack of light, strong pressure vessels and the lack of a practical, economical testing method for natural gas cylinders. At present, pressure vessels used for gaseous fuels or other pressurized gases are retested by periodically removing the cylinder from service and subjecting it to hydrostatic testing at 150 percent of normal service pressure. This procedure is not only costly, but also potentially destructive, as it can weaken the vessel and contribute to early failure.

This project examined the promising alternative of testing based on the acoustic emission signature of the cylinder. Flaws in the structure of a vessel emit sounds that can be detected and analysed to determine the vessel's integrity without subjecting it to excessive stress levels.

The first stage of the project covered materials evaluation for various types of natural gas vehicle cylinders currently available on the Canadian market. Steel cylinders, composite hoop-wrapped steel or aluminum liners, and full composite cylinders were investigated and the data generated were used to develop criteria for acoustic emission testing methods. The next stage included acoustic emission testing during hydrostatic retesting at the cylinder retesting station, and service testing of acoustic emission at the refuelling station. The results of these extensive tests confirmed the feasibility of using acoustic emission procedures for recertifying natural gas vehicle fuel cylinders.

Contractor: Canadian Gas Association, Mississauga, Ontario
Report: None to date
Schedule: February 1989 - November 1990
Funding: Energy R&D Program $225 000
Project Number: 7211
File Number: 1465-461-2
Project Officers:
Doug W. Dibble, Roy S. Nishizaki

Development of acoustic emission as a method of detecting cracks in natural gas cylinders

Natural gas conversion for buses

The replacement of diesel fuel used by urban buses with natural gas could lead to considerable savings and reduced air pollution. An initiative under the Economic and Regional Development Agreement between the Government of Canada and the Province of Quebec, this project will develop a conversion kit enabling bus engines to use natural gas in addition to diesel fuel and will provide in-service operating experience. The DDA 6V-71 and 6V-92 engines were chosen for this research, since they are used in almost 90 percent of the urban buses operating in North America. The conversion kit, once fully developed, could therefore find a ready market in both Canada and the United States.

After studying existing conversion systems designed to convert these engines to a dual fuel mixture of natural gas and diesel fuel, the contractor will develop a new conversion kit that improves efficiency and reduces emissions. The system will then be subjected to a lengthy in-service demonstration with Montreal's urban transport corporation.

Contractor: Gaz Métropolitain Inc., Montreal, Quebec

Report: None to date

Schedule: January 1990 - March 1991

Funding:

Gaz Métropolitain	$169 000
TDC	$84 500
Ministère des Transports du Québec	$84 500
Total	$338 000

Project Number: 7427

File Number: 1465-570

Project Officer: Sesto Vespa

Test bus in service

Traction battery cell

A major impediment to the widespread use of electric vehicles is the lack of trouble-free storage battery systems with high energy to weight and power to weight ratios that can provide economical lifetime service.

Co-funded by TDC and the ministère des Transports du Québec, this Hydro Québec project aims to develop a solid polymer electrolyte cell capable of storing 150 Wh/kg and delivering 140 W/kg.

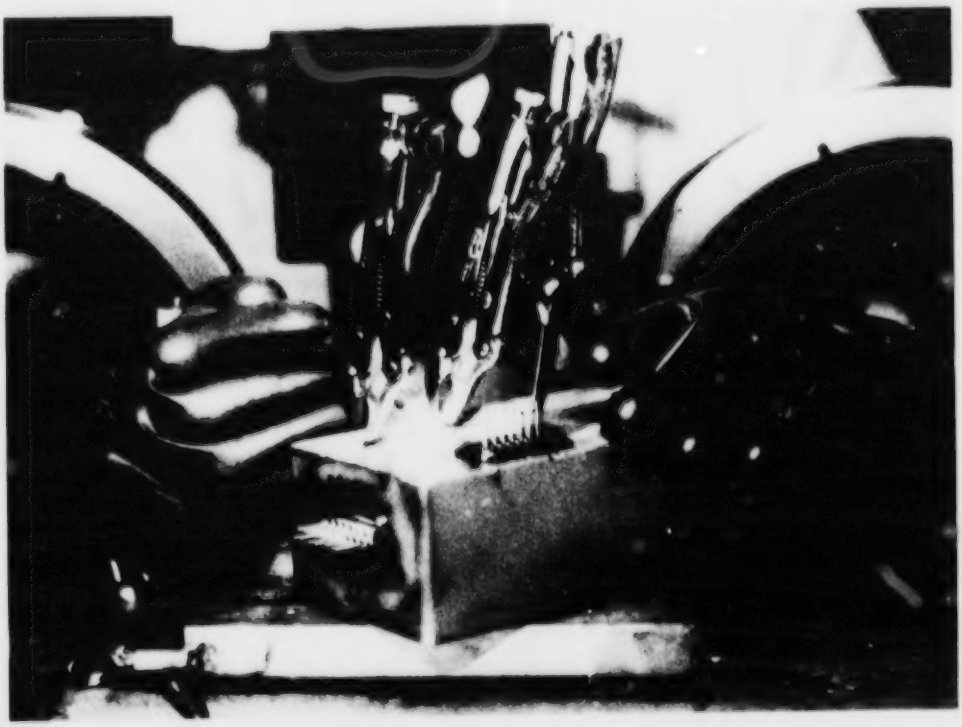
After determination of the optimum anode, cathode, and electrolyte materials, prototype unit cells of 280 Wh will be constructed and tested to identify potential problems. The project will also address manufacturing methods and costs.

Hydro Québec and the Yuasa Battery Co. of Osaka, Japan, have recently formed a new company to conduct further research and to manufacture the battery.

Contractor: Hydro Québec, Montreal, Quebec
Report: None to date
Schedule: April 1990 - December 1991
Funding:

Hydro Québec	$600 000
Ministère des Transports du Québec	$200 000
TDC	$200 000
Total	$1 000 000

Project Number: 7420
File Number: 1465-568
Project Officer: Neil R. Gore



Prototype of 10 Wh solid polymer lithium battery

Integrated traffic system

A microcomputer-based Integrated Traffic System (ITS) is being tested and evaluated in three Ontario locations – Toronto, Ottawa-Carleton, and the Regional Municipality of Durham. An earlier project concluded that such a system could substantially increase the efficiency of traffic management; however, the software available was not integrated into an operational control system and there was no convenient data base for its calibration. In this project, researchers reviewed traffic operations in each area, prepared criteria for a data base, and compiled supporting documentation for users and operators.

ITS permits more effective traffic engineering through the analysis, tabulation, and reporting of traffic accidents. It integrates generic spread sheet and graphic programs and can interface with external data bases. The system's potential benefits include reduction in traffic delays, congestion, and energy consumption. It could also reduce accidents through better analysis of accident data, and cut costs for municipalities through better use of resources.

The project has important commercial potential since this will be the first system of its kind on the market.

Contractor: IBI Group Inc., Toronto, Ontario
Report: None to date
Schedule: January 1987 - September 1990
Funding:

TDC	$260 583
Energy R&D Program	$178 083
Total	$438 666

Project Numbers: 6818, 6819, 6820
File Number: 1465-444-2
Project Officer: John H. Morgan

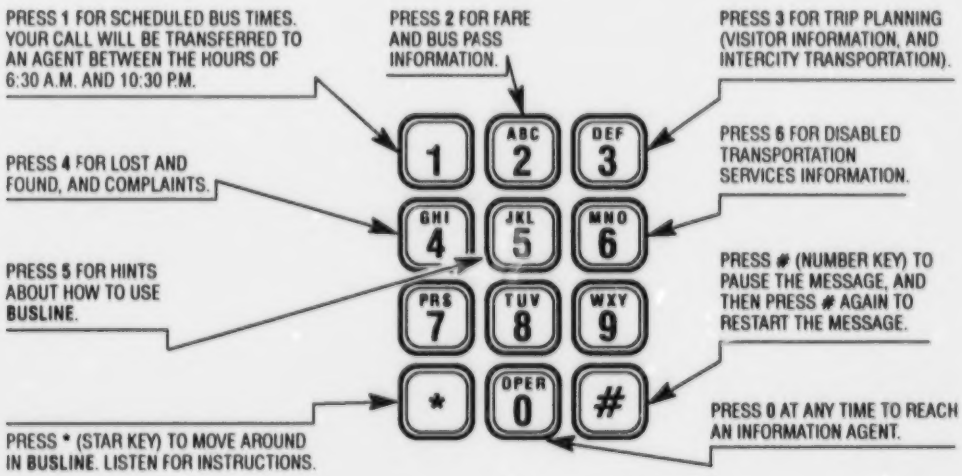
Implementation of an integrated transportation information system

Public transit users in Victoria, B.C., can now obtain up-to-the-minute travel information with a single telephone call. This new Busline is based on an integrated transportation information system, ITIS – computerized voice-based technology that can transmit information by radio, video terminal, and telephone (see also page 140). ITIS was developed by Oracle Communications Inc. of Burnaby, B.C., under an earlier TDC contract.

Busline uses a digitally recorded human voice to provide information on fares, destinations, routes, and schedules. For assistance, travellers simply dial a central number on a touch tone telephone. Staff are available to handle complex inquiries or to assist callers using a rotary dial telephone. Busline was tested in a controlled situation among user groups and feedback from these tests has led to improvements in the system.

The next phase of the implementation will introduce a data base to cross-reference the telephone's location against a computerized map of the city's transit network, identify the nearest bus stop, and tell the user what time the next bus is due. In the final phase of the project, Busline will use mathematical optimization to suggest the quickest, most convenient route from one point to another, and give directions and schedule information. It will also provide information about other public transportation services – ferry and intercity bus schedules, for example.

Contractor: British Columbia Transit, Vancouver, B.C.
Report: None to date
Schedule: March 1989 - March 1991
Funding: $397 660
Project Number: 7241
File Number: 1450-151-2
Project Officer: Ling Suen


PRESS 1 FOR SCHEDULED BUS TIMES. YOUR CALL WILL BE TRANSFERRED TO AN AGENT BETWEEN THE HOURS OF 6:30 A.M. AND 10:30 P.M.
PRESS 2 FOR FARE AND BUS PASS INFORMATION.
PRESS 3 FOR TRIP PLANNING (VISITOR INFORMATION, AND INTERCITY TRANSPORTATION).
PRESS 4 FOR LOST AND FOUND, AND COMPLAINTS.
PRESS 6 FOR DISABLED TRANSPORTATION SERVICES INFORMATION.
PRESS 5 FOR HINTS ABOUT HOW TO USE BUSLINE.
PRESS # (NUMBER KEY) TO PAUSE THE MESSAGE, AND THEN PRESS # AGAIN TO RESTART THE MESSAGE.
PRESS * (STAR KEY) TO MOVE AROUND IN BUSLINE. LISTEN FOR INSTRUCTIONS.
PRESS 0 AT ANY TIME TO REACH AN INFORMATION AGENT.
1
ABC 2
DEF 3
GHI 4
JKL 5
MNO 6
PRS 7
TUV 8
WXY 9
*
OPER 0
#

Instructions for Busline users

RAIL TRANSPORTATION

RAIL TRANSPORTATION

Safe and efficient rail transportation is vital to the Canadian economy. TDC supports research and development projects in rail technology in cooperation with the railways, railway equipment manufacturers, consulting companies, and other research organizations.

Regulatory Support

In January 1989 the Railway Safety Act transferred the responsibility for regulation of the operation and maintenance of railways from the National Transportation Agency to Transport Canada. As a result, TDC's R&D support of the Railway Safety Directorate is expected to increase.

The trend toward improved safety can be attributed to greater public awareness of safety issues and investment in automated warning signals and civil works at grade crossings. A TDC study of Operation Lifesaver, a successful public education program designed to increase public awareness, will be reviewed by the organization board with a view to making the program even more effective.

TDC has undertaken a number of rail-related activities in support of the Transport Dangerous Goods Directorate. The necessary knowledge has already been developed to deal with the effects of external fire on tanks carrying liquefied gases. Researchers have reviewed pressure relief valves, investigated tank failure modes and projectile hazards, and plan to develop a dynamic model of pressure relief valves for pressure liquefied gases.

TDC has also started work on the application of electronic waybilling to railway transportation. The rail mode was considered particularly suited to the introduction of this technology because there are only two major carriers in Canada and the status of computer technology applications in the industry is well advanced.

Advanced Train Control Systems

Advanced Train Control Systems (ATCS) can help to increase operating efficiency and safety. One important area of research is error-free reception of messages through digital mobile communications systems. The railway industry has already adopted an encoder-decoder (CODEC) that uses a Reed-Solomon error detection and correction code. Microprocessor implementations of this CODEC have been developed under a TDC contract and an application-specific integrated circuit (ASIC) implementation is currently under development. The advantages of this ASIC implementation are high speed, low encoding-decoding delay, low component count, low power consumption, and high reliability.

System Safety

TDC collaborates with railway companies and appropriate university, research, and industrial organizations in support of system safety R&D. As well as contributing to safety, activities must offer sufficient incentive to private sector partners to ensure that the resulting technology is implemented.

The first phase of a project on the use of guided radar to detect rock slides identified a promising leaky waveguide configuration for further study. TDC's recent work on non-destructive evaluation techniques is expected to become increasingly important. Current work looks at the use of electro-magnetic acoustic transducers to map residual stresses in rails. If successful, this work would result in a laboratory technique that could be used in steel mills for quality control of rail. This technique could also have other applications such as in-situ rail inspection or inspection of wheels for excessive residual stresses in the rims due to thermal damage. Other activities currently include laser vision

inspection of rail longitudinal profiles and the measurement of fracture toughness of rails as a function of ambient temperature.

Energy Efficiency and Alternative Fuels

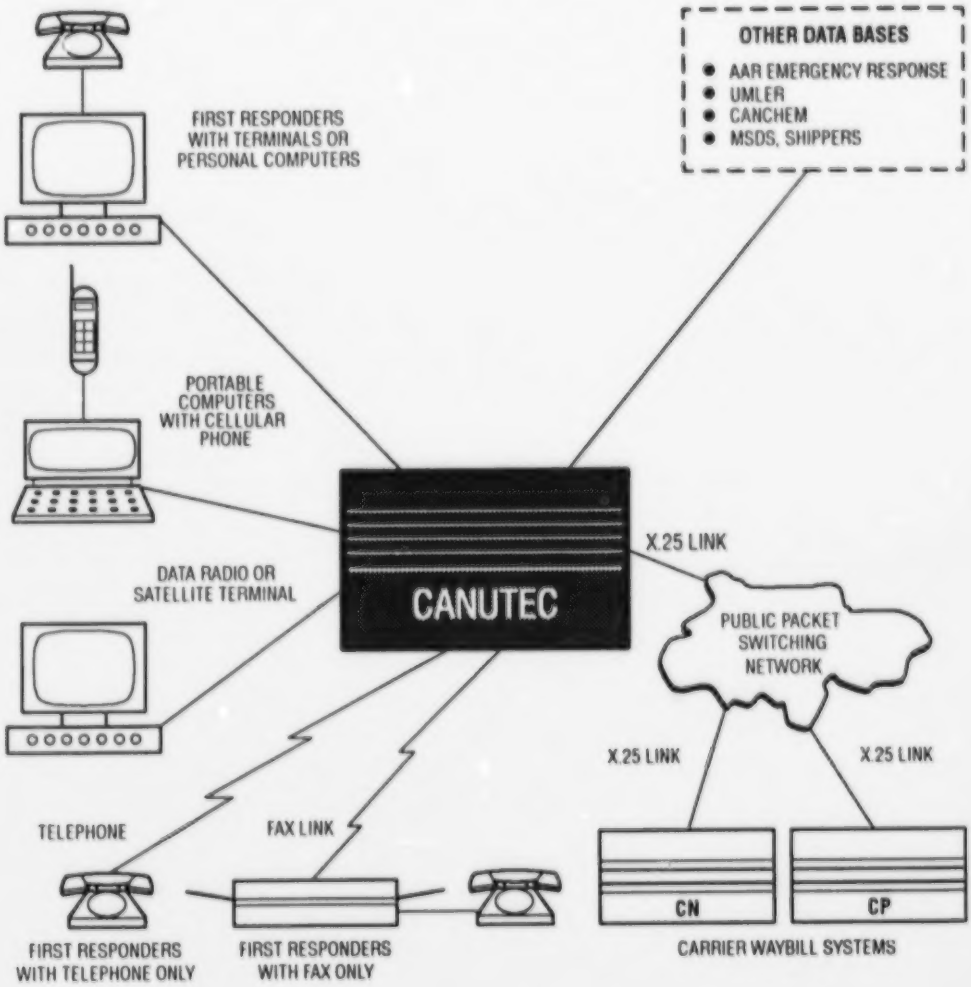
In keeping with its long-term support of cooperative research efforts with the railways to improve energy efficiency, TDC sponsored an initiative to develop prototype fuel-saving devices for locomotives of the Quebec North Shore and Labrador Railway. Subsequently, the railway purchased the equipment for its locomotive fleet, and personnel were trained in the operation and maintenance of the fuel savers. Data acquired on the results of the initial period of operation should enable the industry to assess the usefulness of this device.

Rail Technology Evaluation

In cooperation with industry, TDC undertakes exploratory R&D involving systematic assessment of new developments. Areas currently under investigation include the application of thermally sprayed coatings to cylinder liners for diesel engines and the enhancement of computer model capabilities for analysis of the stability of railway embankments.

High Speed and Commuter Rail

Innovative technology may introduce major changes to the transportation system; TDC endeavours to maintain a basic understanding of new technologies that may affect the Canadian rail network. One area of current interest is advanced linear induction motor control systems.



Canutec, Transport Canada's emergency response centre, would act as a central information source for the proposed electronic waybill.

Electronic waybill for the transport of dangerous goods

Transport Canada is responsible for the transportation of dangerous goods – over 3000 such products are currently listed in Canada. In almost all cases, train personnel must have an Emergency Response Form for rail cars carrying a full load of one of these products. The form identifies the dangerous commodity, its properties, action to be taken as a result of an accident, and shipping information. The format and content of this form are strictly regulated.

This project is examining the use of Electronic Data Interchange to automate this form with a view to reducing paperwork while ensuring compliance with emergency response requirements. The needs of those responding to an accident involving dangerous goods are of primary importance. The efficiency and effectiveness of emergency response personnel could be improved by providing them with an electronic mechanism for delivering timely, precise, and correct response information.

The first phase of this project investigated the general state of shipping document automation in the rail industry through Electronic Data Interchange, and then studied the possible automation of emergency response information. Researchers conducted a comprehensive survey of the Canadian rail industry and pertinent literature, and met with representatives of the rail, shipping, and emergency response communities. The second phase will focus on setting up a small-scale demonstration of an electronic waybill system for use by the railways. This prototype will be evaluated against the current emergency response form, using various simulated situations to pinpoint where and how information would be introduced into the system. The legal aspects of implementing such a facility will be examined, taking into account the Transportation of Dangerous Goods Act & Regulations. Legislative changes required for such implementation will then be documented and appropriate action recommended.

Contractor: Automation Technologies Group Ltd., Montreal, Quebec
Report: None to date
Schedule: November 1989 - January 1991
Funding: $91 521
Project Number: 7232
File Number: 1465-538
Project Officer: Lewis Sabounghi

Many of the 3000 hazardous products listed by Transport Canada are carried by rail. *(Photo courtesy of CN Rail)*

Modelling the effects of fire on tank cars

The transport of dangerous goods, although essential to Canada's economy, presents a potential threat to human life and the environment. The storage and transport of these goods must be subject to the highest safety standards. This project is studying various methods to minimize the risks arising when a tank car carrying pressure liquefied gases is engulfed by fire.

One objective of this research is to increase understanding of the mechanisms that lead to the reduced performance of the pressure relief valve in transportation and storage of pressure liquefied gases. This valve plays a critical part in the response to a fire surrounding a tank carrying dangerous goods. If it does not open, the tank, no matter how well insulated, will eventually rupture. Further research is needed to adequately understand the operation of the pressure relief valve. Using a thermal model developed at Queen's University in work begun in 1981, the project will develop a dynamic model of a pressure relief valve that will be incorporated into the tank thermal model. It will also test the operating characteristics of valves.

An apparatus is also being constructed to study the single and two-phase flow operating characteristics of a pressure relief valve for rail tank cars. Tests will then determine the effects of factors such as valve age and condition, valve temperature, flow void fraction, valve inlet and exit conditions, and valve design. Researchers will focus on obtaining data on valve operations in real situations.

Contractor: Department of Mechanical Engineering, Queen's University, Kingston, Ontario

Reports:
TP 10049E, State-of-the-art review of pressure relief device design, testing, and modeling, Department of Mechanical Engineering, Queen's University, 1990

TP 10050E, State-of-the-art review of pressure liquefied gas container failure modes and associated projectile hazards, Department of Mechanical Engineering, Queen's University, 1990

Schedule: February 1989 – March 1992
Funding: $150 000
Project Number: 7215
File Number: 1465-302-6-7
Project Officers: Doug W. Dibble, Neil R. Gore

Assessment of Operation Lifesaver

Established in 1981, Operation Lifesaver is designed to promote public awareness of railway/road grade crossing hazards. The National Office, funded jointly by the Railway Association of Canada and the Railway Safety Directorate of Transport Canada, promotes and coordinates the Operation Lifesaver activities of provincial safety councils and other participating organizations; produces and distributes educational literature and audio-visual material; devises and organizes events such as special awareness days; produces radio and TV public safety messages; and provides or arranges speakers for special interest groups.

The federal Government Consulting Group reviewed the program on behalf of TDC, which was requested by the funding sponsors to assist in evaluating its effectiveness and efficiency.

It was concluded that Operation Lifesaver had made a significant contribution to the marked reductions in accidents, injuries, and fatalities since the program was inaugurated.

The effectiveness of the Operation Lifesaver program compares most favourably with other public education programs and it can be considered a model in terms of generating and maintaining the interest and involvement of a broad spectrum of organizations concerned with public safety.

Contractor: Government Consulting Group, Ottawa, Ontario
Report: TP 10377E, Review of Operation Lifesaver Program, Government Consulting Group, 1990
Schedule: May 1989 - June 1990
Funding: $48 000
Project Number: 7305
File Number: 1465-560
Project Officer: Neil R. Gore

There are 26 000 public railway crossings in Canada.

Application-specific integrated circuit for ATCS

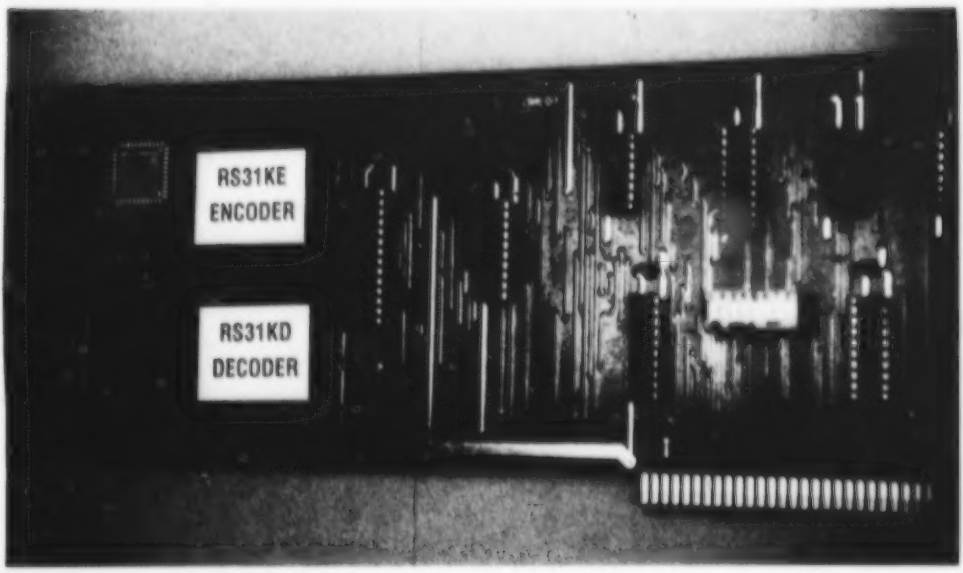
This project involves the implementation of a customized coding scheme for forward error correction, designed to ensure data integrity for the digital communication links required for advanced train control systems (ATCS). Advanced train control systems will rely heavily on mobile digital communication links for both vital and other information exchanges between trains, track maintenance forces, and wayside radio installations linked to central command offices. The stringent requirements of railway operations, together with the finite capacity of the assigned radio spectrum, impose corresponding constraints on message error rates.

Researchers sought to design, develop, and demonstrate a programmable (31 k) Reed-Solomon encoder-decoder (CODEC) and to implement it by means of an efficient application-specific integrated circuit (ASIC). To select the most efficient design, a comparative study of the speed and complexity of different CODEC algorithms was completed. A prototype CODEC was constructed, tested, and evaluated and a prototype ASIC gate array design was developed to the production stage.

The advantages of an ASIC-based implementation of the CODEC are high speed, low encoding/decoding delay, low component count, low power consumption, and high reliability.

The extensive testing that began after the limited production of two chips – the encoder and decoder – for evaluation is still under way. This important work has the potential for application to data communications in all modes of transportation as a means of correcting mobile radio digital transmissions.

Contractor: Binary Communications Inc., Victoria, B.C.
Report: None to date
Schedule: August 1989 - December 1990
Funding: $267 800
Project Numbers: 7306, 7307, 7308, 7309
File Number: 1465-514-2
Project Officer: Wayne G. Rowan



Interface board containing encoder and decoder chips

Safety considerations in implementation of ATCS-type systems

ATCS and ATCS-type systems are already being developed in Canada and are expected to be introduced on a wide scale in the not-too-distant future. The commissioning of these systems requires adaptation to a new technology incorporating microprocessors and data communications links in vital roles. Throughout the world, railway authorities are concerned about the introduction of processor-based equipment, which often does not fit existing rules, for vital or fail-safe functions. This project examined the safety issues associated with the design, development, testing, and operation of such systems. In addition, researchers conducted a literature survey and evaluated ten ATCS-type systems in Europe and North America, to provide a description of the programs undertaken by users and government agencies, worldwide, to address these issues and to assure system safety.

They found no specific rules or regulations on the safety issues associated with processor/software-based vital systems, although most rail systems with rolling stock, train control, or vital sub-systems using software-based processors have implemented a Safety Assurance Plan or its equivalent. These plans usually examine the entire system, thus including software safety.

Two of the four phases of this project have been completed. Proposed future work is under review and may be reoriented to respond to evolving needs within Transport Canada.

Contractor: Tom Parkinson Transport Consulting Ltd., Vancouver, B.C.
Report: None to date
Schedule: March 1989 - July 1989
Funding: $15 000
Project Numbers: 7251, 7252
File Number: 1465-508
Project Officer: Sesto Vespa

Landslide detection by guided radar

Unexpected slides of rock, earth, and snow present serious hazards to railroad operation, especially in the mountainous regions of Western Canada. Maintenance and repair to slide detection equipment is costly, contributes to train delays, and exposes work crews to both falling material and traffic hazards.

Current methods of detection damage the system and are susceptible to false alarms. A reliable, non-destructive detection system would greatly improve both operating efficiency and safety.

This project studied the feasibility of implementing a railway slide detection system using guided radar technology, which directs radio frequency surface waves by the use of leaky coaxial cables. These are similar in construction to standard coaxial cables, but the outer conductor is modified to allow a controlled amount of radio frequency energy to leak out of the cable. In perimeter applications, a transmit and receive leaky coaxial cable is buried around the area to be secured. An intruder will disturb the cable resulting in a change in the received signal. The technology can be adapted to rockfall detection by modifying the processing to look for sudden and permanent changes in the received signal rather than for gradual temporary changes.

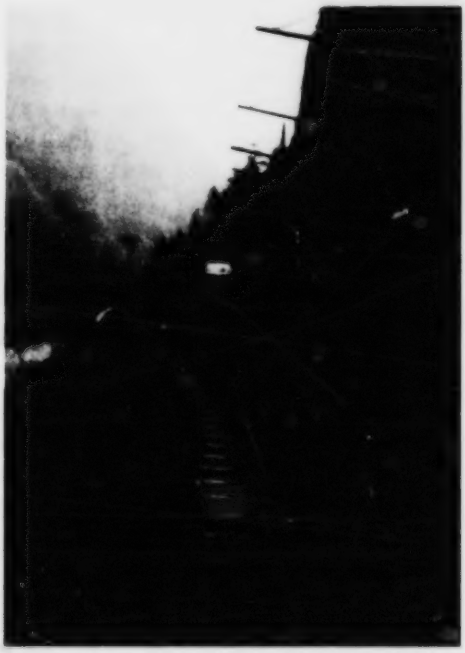
Requirements for a landslide detection system were determined by discussions with CN personnel and by a field trip to examine slide zones in British Columbia. A series of tests was then designed to determine whether guided radar could meet these criteria. The results of the first series of tests showed that guided radar can meet the specified requirements, and two configurations for further testing were identified.

Work is proceeding on field tests and analysis; if these tests are successful, a full-scale system will be installed in the Fraser Canyon.

Contractor: Senstar Corporation, Carp, Ontario
Report: None to date
Schedule: February 1989 - October 1991
Funding:

Senstar Corporation – equipment in-kind	
CN Rail – labour in-kind	
TDC	$343 578
Supply and Services Canada	$107 354
Total	$450 932

Project Numbers: 7100, 7101
File Number: 1465-524
Project Officer: Wayne G. Rowan



Radar detection test site near Boston Bar, B.C., showing cantilevered slide fence in current use

Track structure research

Railway track is frequently subjected to moving axle loads. Because of vehicle speed, wheel imperfections, and track geometry deviations, the dynamic loads transmitted to the various track components can be much higher than the static loads. Wheel imperfections are the biggest source of track overloading and subsequent track degradation and component failure. Rails and ties (especially concrete ties) are most susceptible to defective wheels. In winter, the frozen track bed and the increased tensile stresses in the rail itself add to track stiffness, increasing the probability of rail fracture.

To determine the effects of wheel loading on their tracks, Canadian railways have equipped test sites with devices that measure wheel load and identify defective wheels through the use of rail-mounted strain gauge rosettes that measure shear stresses along a short section of rail. The gauges are calibrated under monotonically increasing static loads using a self-equilibrating frame. The "static versus strain" calibration chart derived is used as a standard for establishing wheel loads of moving trains; however, the accuracy of the calibration of these systems and their ability to measure dynamic loads has been challenged. Furthermore, railways need to determine the dynamic load capacities of the rails themselves over a wide range of temperatures.

This project aims to address these problems through increased understanding of the loads generated by railway vehicles and setting of operational limits on those loads based on the capacity of individual track components. Fracture toughness tests on worn rail samples of varying weights taken from CN and CP track are being conducted at the cold temperature facility at Queen's University. The calibration of existing wheel load measurement devices may lead to the design of a low-cost version. Researchers will also develop software to interpret the data provided by the wheel load detector.

Contractor: Canadian Institute of Guided Ground Transport, Queen's University, Kingston, Ontario

Report: None to date

Schedule: May 1989 - May 1992

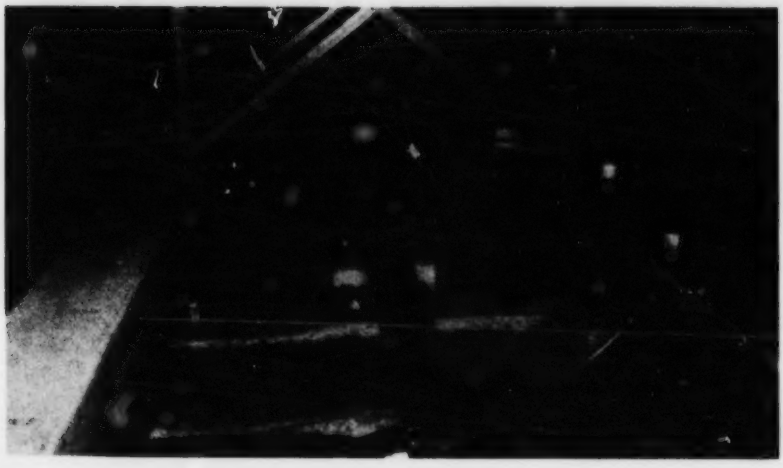
Funding:

TDC	$135 000	
CN	$115 000	+ in-kind
CP Rail	$80 000	+ in-kind
Total	$330 000	

Project Number: 7255

File Number: 1465-401-3

Project Officer: Wayne G. Rowan



Laboratory test set-up at Queen's University

Laser vision system for rail inspection

This project investigated the feasibility of applying synchronized laser scanner technology to high-speed rail inspection by developing a vision system that could accurately measure both transverse and longitudinal railhead profiles. High-speed automated inspection is expected to assume an increasingly important role in the safe and economical maintenance of the railway track system. Non-contact measurement devices are preferred by railways and track maintenance contractors for safety-related inspections of rail because non-contact transducers do not require repair and replacement as frequently as their mechanical (contact) counterparts. To be applicable to railway inspection, a scanner must be able to withstand severe environmental conditions, including strong shocks and vibrations, wide temperature fluctuations, and variations in lighting for day and night operations.

In an earlier phase of this project, researchers subjected a laser vision camera, developed by Servo-Robot Inc. of Boucherville, Quebec, to laboratory testing in a simulated railroad environment. It was then modified, mounted under a railway car, and subjected to field tests. The test car passed over the same zones at different speeds, collecting data on the distance from the car body to the rail surface sampled at 1.5″ intervals. The raw data was processed using specially written software that removed the wavelengths outside the range of interest from the signal.

The success of these field tests proves the capability of the laser vision camera to obtain accurate measurements under operating conditions. CP Rail intends to continue further testing to verify the camera's capacity to perform satisfactorily over longer distances and in extreme weather conditions.

Contractor: Canadian Pacific Ltd., Montreal, Quebec

Report: TP 10215E, Feasibility study of utilizing a synchronized laser scanner for rail inspection, CP Rail, 1990

Schedule: May 1988 - June 1990

Funding:

Energy R&D Program	$153 500
CP Rail	$153 500
Total	$307 000

Project Number: 7020

File Number: 1465-523

Project Officer: Doug W. Dibble

View of laser vision system installed on CP track geometry car to measure rail corrugations

Measurement of residual stress in rail

The railways are concerned about the level of residual stress induced in rail as the result of manufacturing, heat treatment, and straightening processes. These stresses can add to those imposed by operational loads and extremes of temperature.

The measurement of residual stress in new rail products is being addressed through two related TDC projects.

A project to investigate the feasibility of using EMAT (electro-magnetic acoustic transducer) technology to determine residual stress by the measurement of shear wave birefringence in steel is being jointly funded by the prime contractor, Permatrack Systems Inc., and TDC.

Chalk River Nuclear Laboratories of Atomic Energy of Canada Ltd. is undertaking a complementary TDC project involving the measurement of residual stress in rail sections using neutron diffraction techniques to corroborate results obtained from the Permatrack/TDC study.

Contractor: Permatrack Systems Inc., Vancouver, B.C.
Report: None to date
Schedule: March 1989 - August 1991
Funding:

TDC	$43 000
Permatrack Systems Inc.	$14 000
Total	$57 000

Project Number: 7242
File Number: 1465-553
Project Officer: Neil R. Gore

Contractor: Chalk River Nuclear Laboratories, Atomic Energy of Canada, Chalk River, Ontario
Report: None to date
Schedule: November 1989 - September 1990
Funding: $38 725
Project Number: 7428
File Number: 1465-57
Project Officer: Neil R. Gore

Locomotive fuel saver

This project developed a fuel-saving system that automatically stops and starts a locomotive engine. Researchers also verified the actual fuel savings and provided performance data for potential manufacturing and marketing of the device. Initial laboratory development and bench testing of a device designed and built by Dynamic Sciences Limited (based on a concept of the Quebec North Shore and Labrador Railway) were followed by laboratory and field testing of prototype and pre-production units. Development included the design and construction of a microprocessor control unit.

The system saves fuel by shutting down the locomotive engine, rather than allowing it to idle when it is not in use. The engine temperature is monitored - when it cools to 38°C, the engine is automatically restarted and runs until the temperature reaches 55°C. The fuel-saving system consists of a main control unit, a display and control panel, a consist control panel, and a set of sensors and actuators. The highly sophisticated device uses a microprocessor to control all aspects of the system. The signals between the microprocessor and the remote interface unit are connected by a single fibre-optic cable. The use of the fibre-optic cable eliminates the electrical interference normally expected with conventional cable.

The demonstrated fuel savings are significant. They depend not only on time spent in the fuel-saving mode but also on ambient temperature. Conservative estimates of yearly savings are approximately $8 000 per locomotive based on fuel costs of $0.26 per litre.

Commercial potential of this device will be determined by fuel costs, but increasing concern over the environment could give rise to a shut-down policy for locomotives. If such a policy were introduced, a device such as the fuel saver would be needed in colder climates, particularly during extended shut-downs.

Contractor: Dynamic Sciences Ltd., St. Laurent, Quebec

Report: None to date

Schedule: December 1984 - June 1990

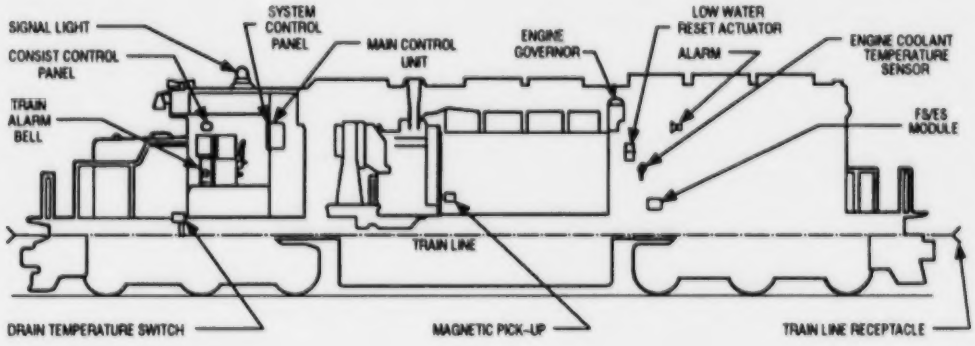
Funding:

Supply and Services Canada	$126 373
TDC (Augmented Rail Freight Program)	$115 034
Energy R&D Program	$100 000
Total	$341 407

Project Numbers: 6314, 6315, 6316

File Number: 1465-448-1

Project Officer: Doug W. Dibble



Consist control panel for locomotive fuel saver

Low-tare aluminum coal car

This project is designed to determine the potential of aluminum coal cars to improve the economic performance of rail transport of coal.

Currently coal cars are made of steel, and the lightest steel car in use is the CP Rail bathtub gondola, which has a tare weight of 53 000 pounds. The target weight of the aluminum car is between 43 000 and 44 000 pounds. This nine to ten thousand pound difference could be replaced with coal.

Earlier Canadian attempts to introduce aluminum coal cars have not met with great success. However, new understanding of fatigue problems observed in these cars and a new transfer extrusion process developed by Alcan will assist researchers in the current work.

The proposed design for the new aluminum coal car was reviewed by the project review committee, with members from CP Rail, Alcan, National Steel Car, and TDC. One car will be constructed and tested in standard unit-train operational service for two years.

Adoption of this aluminum car could improve the competitiveness of Canadian coal in the marketplace by decreasing transportation costs.

Contractor: Alcan International Ltd., Montreal, Quebec
Report: None to date
Schedule: March 1990 - September 1992
Funding: Energy R&D Program $169 983
Project Number: 7291
File Number: 1465-551
Project Officers:
Doug W. Dibble, William S.C. McLaren

Lightweight aluminum coal car

Track substructure model

This research began in 1984 as part of a long-term cooperative research program among universities, consultants, railways, and the federal government. The third stage of this project sought to extend the usefulness of the enhanced GEOTRACK computer model in analysing subgrade stability.

Originally, the emphasis was to be placed on modification of GEOTRACK to accommodate embankment side-slopes. However, a parametric study revealed that embankment side-slopes have little effect on the vertical, horizontal, and shear stress distributions beneath the loaded structure. The study was therefore extended to investigate more fully the effect of embankment side-slope on bearing capacity. Slope stability analyses for soils with negative pore-water pressures complemented the study. Researchers noted that bearing capacity:

- decreases with a large inclination of slope, particularly in granular materials;
- decreases with overall height of a slope, particularly in cohesive materials; and
- becomes independent of slope height at greater distances from the edge of the slope.

The study has added to the understanding of track support behaviour under load and has shown that soil bearing strength can be increased through the matric suction effect of the soil itself. The software programs developed, together with the family of design charts, will be used extensively by railway track engineers for both new construction and major rehabilitation projects on existing track structures.

Contractor: Department of Civil Engineering, University of Saskatchewan, Saskatoon, Saskatchewan

Reports:

TP 10217E, Subgrade design model extension, Department of Civil Engineering, University of Saskatchewan, 1990

TP 9523E, User's manual, second edition: Geotrack and geoplot, stress, bearing, and compare (subgrade stress analysis and bearing capacity), Department of Civil Engineering, University of Saskatchewan, 1990

Schedule: April 1989 - June 1990

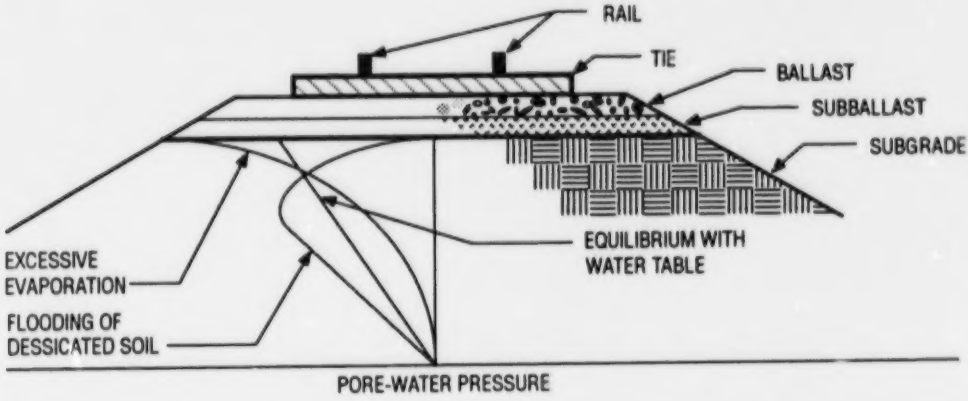
Funding:

TDC	$27 600
CP Rail	$27 600
Total	$55 200

Project Number: 7271

File Number: 1465-438-4

Project Officer: Wayne G. Rowan



Typical schematic pore-water pressure profile

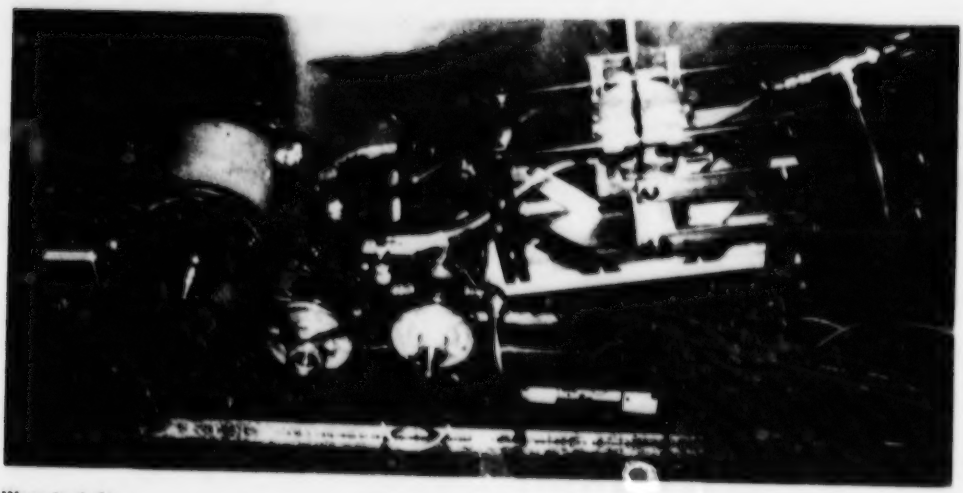
Evaluation of diesel engine liner coatings

At present, thousands of locomotive diesel engine cylinder liners are recycled every year by electroplating the wear surface with chrome. This process has several drawbacks: it involves hazardous chemicals associated with environmental problems; it is very slow; and the supply of materials is subject to the international political situation. In addition, the cylinders can be chrome plated only if the liner wear is within a narrow tolerance. Alternative coating technology could mean greater salvage of worn linings, improved durability, and a reduction in the environmental pollution hazard inherent in chrome plating.

This study is investigating the application of thermally sprayed coatings as a fast, cost-effective method of refurbishing worn liners on medium-speed diesel engines.

To date, the contractor has selected and prepared coated samples, which have been characterized and subjected to physical testing. A wear test rig has been designed and constructed. If successful in finding an alternative to current technology, this project will benefit both the coating industry and the railways.

Contractor: Department of Mechanical Engineering, University of Manitoba, Winnipeg, Manitoba
Report: None to date
Schedule: September 1989 – March 1991
Funding: $39 702
Project Number: 7319
File Number: 1465-561
Project Officer: Roy S. Nishizaki



Wear test rig

Fabricated high-speed rail truck

This four-year project involves the design, manufacture, and testing of a fabricated train bogey for high-speed intercity and commuter trains, adapted to North American operating conditions. Funded by the Economic and Regional Development Agreement (ERDA) between the federal government and the province of Quebec, the project responds to ERDA's mandate to strengthen the transportation equipment manufacturing sector in Quebec through research and development aimed at bringing new products to market.

Following design and conceptual studies, a truck frame was built and tested under static and fatigue loads and found to be fully satisfactory. Two prototype trucks were also constructed, fully instrumented, and successfully field tested. These prototypes are being evaluated in revenue service where their performance and ease of maintenance are considered very satisfactory.

Contractor: Bombardier Inc., Montreal, Quebec

Report: TP 8886F, Bogie mécano-soudé destiné au transport interurbain, Bombardier Inc., 1988

Schedule: November 1986 - March 1991

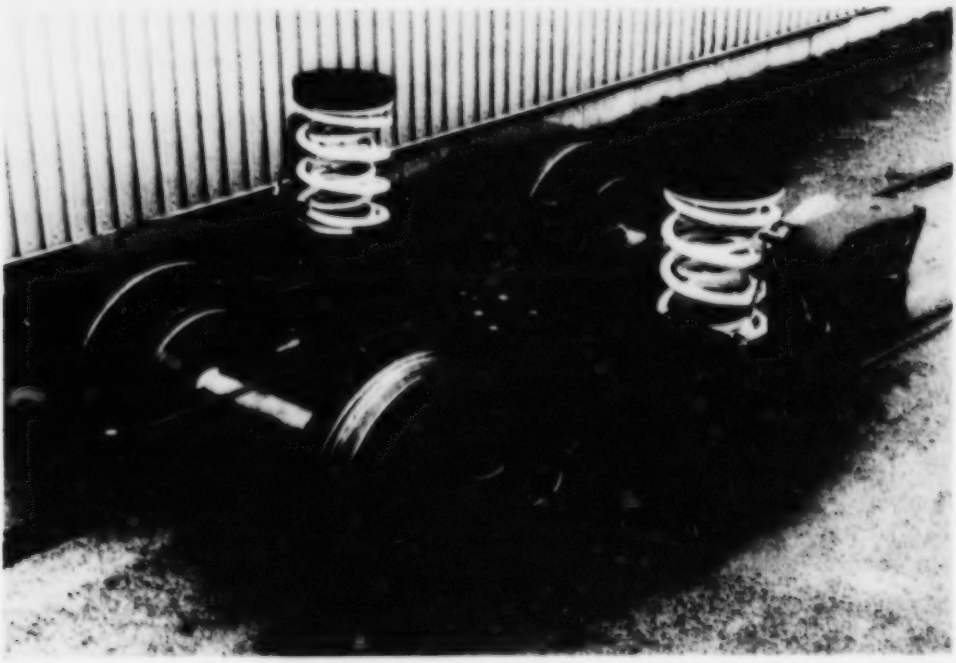
Funding:

Bombardier Inc.	$1 430 000
Ministère des Transports du Québec	$1 035 000
Transport Canada	$1 035 000
Total	$3 500 000

Project Number: 6775

File Number: 1465-497

Project Officer: C. Alfred Versailles



Pre-production prototype bogey

Generic high-capacity subway car body

A generic subway car body, adaptable to the needs of transit companies in North America and overseas, is being developed and built under this project funded by the Canada-Quebec Economic and Regional Development Agreement. A generic car body will allow the manufacturer, Bombardier Inc., to modify the design to quickly meet customer requests for subway cars for any truck and track configuration.

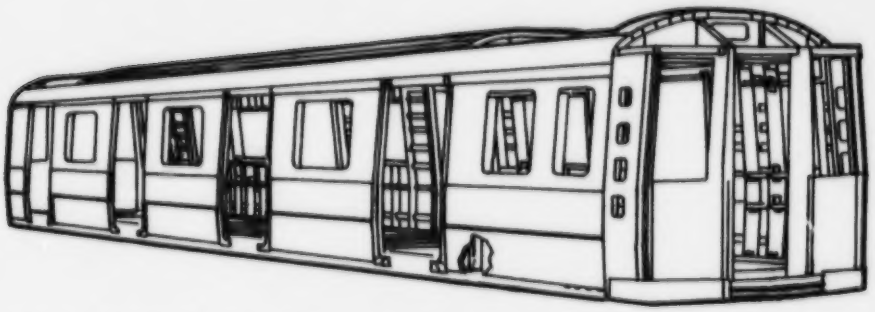
Following the completion of the conceptual design, the stainless steel car body was constructed – requiring Bombardier to develop new modular assembly jigs – and fully instrumented. Another important innovation, a state-of-the-art robotized assembly tooling for spot welding of the car roof, reduces time-consuming hand work, thereby decreasing costs and making the equipment more competitive.

Results of the tests on the new car body are being compiled and analysed.

Contractor: Bombardier Inc., Montreal, Quebec
Report: TP 9056F, Caisse de métro de type grand gabarit, Bombardier Inc., 1988
Schedule: January 1987 - September 1990
Funding:

Bombardier Inc.	$1 222 000
Transport Canada	$889 000
Ministère des Transports du Québec	$889 000
Total	$3 000 000

Project Number: 6854
File Number: 1465-505
Project Officer: C. Alfred Versailles



Sketch of generic subway car body

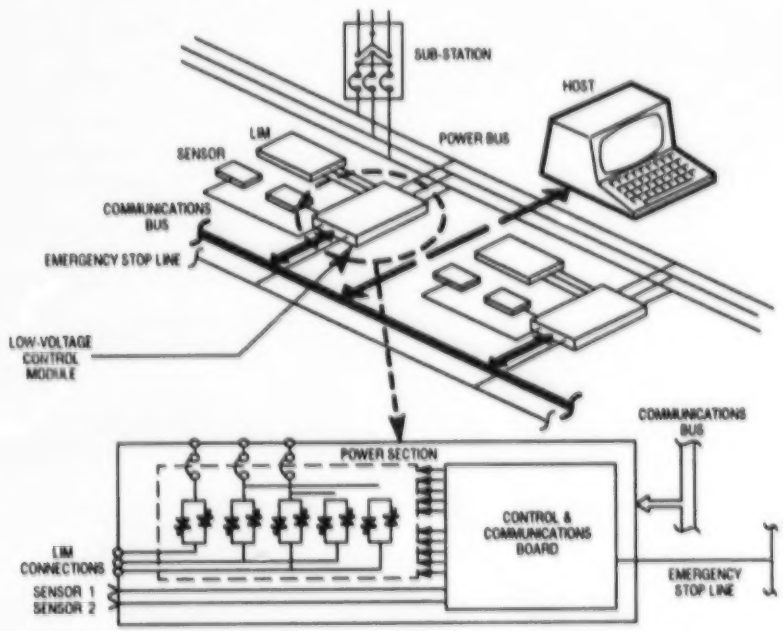
Advanced LIM control system

TDC has been supporting research into linear induction motor (LIM) technology for several years. This project is designed to develop an advanced LIM control system that makes optimal use of LIM capabilities under varying operating conditions. Improved operating performance and reduced system costs are essential if LIM is to remain competitive as an electric propulsion system. One area where significant improvement appears possible is in LIM control software and hardware.

The performance of a linear induction motor depends on many more variables than does its rotary counterpart. The control system should cope with all of these variations and adjust to optimum working point for the motor. Currently available controls, however, are based on analog technology and allow only a limited adaptation of the motor operating point to changing conditions. New microprocessor technology makes it possible to build smarter control systems for LIM drives. Functions that currently exist as "hardwired" logic or analog signal processing circuits may be greatly enhanced by implementing them in software. The contractor is undertaking a development program for an Integrated Vehicle Control and Communication System. This program will provide the basic hardware required to accommodate an advanced LIM control. By reducing the uncontrollable variables that affect LIM operation, new simpler LIMs with fewer design margins can be developed.

Researchers are emphasizing the development of more effective controls for high power on-board LIMs, as advancement in this area offers the greatest potential for performance improvement. The results, however, can also be applied to control of in-track LIMs.

Contractor: UTDC Inc., Kingston, Ontario
Report: *(From previous research)* TP 9308E, Linear induction motors and their control systems, UTDC Inc., 1988
Schedule: July 1989 - July 1991
Funding: $356 485
Project Number: 7292
File Number: 1465-427-5
Project Officer: C. Alfred Versailles



LIM-in-track propulsion configuration. Sensors are located on both sides of the LIM so that the train can be detected from either direction.

ACCESSIBLE TRANSPORTATION

ACCESSIBLE TRANSPORTATION

Transport Canada supports a multimodal R&D program aimed at improving the accessibility of transportation for Canadian travellers, especially elderly and disabled persons. TDC's work in this area reflects the priorities established by the Program Management Committee for Transport Canada's Transportation for Disabled Persons Program (TDPP), which in turn responds to concerns expressed by the Advisory Committee on Accessible Transportation, a national body representing consumer and industry groups.

Vehicle Accessibility

TDC sponsors the development of equipment, systems, and procedures designed to make the entire travel continuum accessible – from trip origin, through terminals and transfer points, to destination – and to provide adequate services and facilities to travellers with hearing, sight, or speech impairments as well as to those who have motor disabilities.

Intercity buses offer one of the most affordable means of long-distance travel for many Canadians. TDC's intercity bus program has led to major advances through the development of internal wheelchair lift technology. A 45-foot bus that sets new standards for accessibility is being demonstrated to interested organizations. As well as a lift that can be operated from inside or outside the coach, the bus has a uniquely designed washroom. Lift-equipped buses are also being evaluated in a demonstration of a fully integrated accessible intercity bus service in the Hamilton-Niagara corridor.

The demand for accessible urban transportation is increasing, and TDC is supporting work designed to make such transportation feasible for conventional taxi companies and to sensitize taxi drivers to the needs of elderly and disabled passengers.

Since deregulation has changed the airline infrastructure, accessibility of smaller feeder and commuter aircraft has become a major concern. TDC has responded by focussing its research on terminal to aircraft transfer for small aircraft and small airports, storage of mobility aids on board larger aircraft, and accessibility of terminal facilities.

TDC is also assisting Transport Canada's Marine Group to assess the recommendations from a recent project on ferry accessibility and to develop, evaluate, and demonstrate boarding and transfer devices designed to enable disabled persons to use Canadian ferries.

Safety

The most critical issue affecting the safety of elderly and disabled travellers is the lack of national transportation standards for vehicles, wheelchairs, and mobility aids. TDC is supporting work aimed at defining what constitutes a transportable wheelchair, revising the Canadian Standards Association's vehicle standard D 409, and developing standards for mobility-aid securement and passenger restraint systems.

While driving represents a major step toward independence for those who have suffered brain damage, maintenance of public and personal safety is of primary concern. The low-cost, high-fidelity driving simulator being developed in work sponsored by TDC is designed to evaluate and retrain brain-damaged drivers. The simulator will also have broad application to other testing and research.

Communication and Orientation

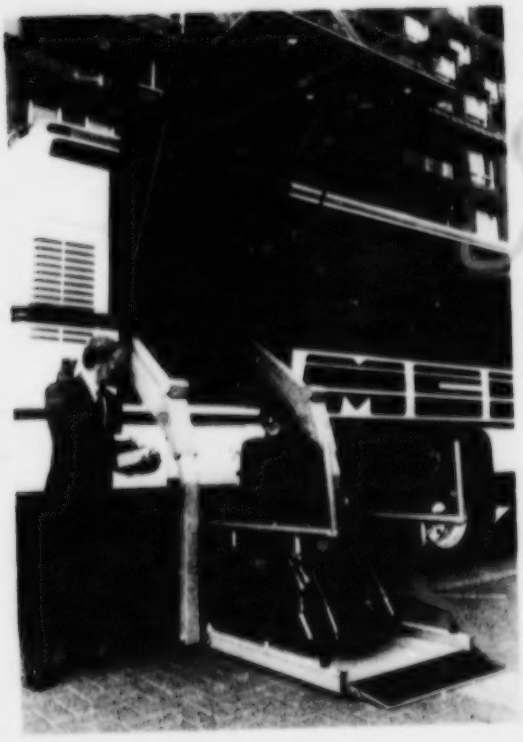
Canadians with disabilities cannot be treated as a homogeneous group. A comprehensive data base profiling the elderly and disabled population in Canada will aid in planning for their transportation needs.

While most of TDC's work relates to the physically disabled, more than 40 percent of the disabled population is made up of people with sight, hearing, or speech impairments. The solutions to their travel problems lie less in further R&D than in the

implementation of current technology that can help them with communication and orientation in vehicles and terminals as well as with travel arrangements.

TDC is supporting the development of a subway communication system that provides information to sensory impaired passengers. It is also sponsoring a demonstration of HandyLine, an adaptation of telephone communications that permits automatic reservation and confirmation of requests for paratransit services.

Although the transportation problems of cognitively impaired travellers remain difficult to define, TDC will continue its research on the elimination of communication and orientation barriers through modern microelectronic and informatics technology. It will also investigate the merits of training and education for both potential travellers and travel service personnel.



On-board wheelchair lift

Sliding doors partition the rear of the bus from the lavatory/vestibule.

Lavatory washbasin slides out to facilitate use from either a seated or a standing position.

Accessible 45-foot intercity coach

North America's first 45-foot, fully accessible intercity coach has been developed by Motor Coach Industries in work supported by TDC. The coach was designed to provide complete accessibility for elderly and disabled travellers as well as all the amenities of a luxury highway coach. The extra length allows the bus to be equipped with both an accessible washroom and a built-in wheelchair lift and still operate economically.

The hydraulic wheelchair lift can be operated by the driver from inside or outside the coach. A manual back-up system can be used in emergencies. The lift has a capacity of 800 pounds and can accommodate both manual and powered wheelchairs. Retractable grab rails and a non-skid surface on the ramp provide extra security, while the overhead door serves as a canopy to protect passengers in inclement weather.

At the rear of the coach, sliding doors operated by push buttons open to a lavatory designed to accommodate passengers with a broad range of disabilities, from restricted mobility to impaired vision. A combined manoeuvring area/vestibule is large enough to allow most wheelchairs to make a full 360-degree turn. A uniquely designed swivelling toilet permits access from either the right or the left side, and the washbasin slides out to facilitate use from either a seated or a standing position. The water faucet is automatically activated by an infrared sensor when hands are placed underneath. Full illumination, a sloping mirror, and large switches and controls provide additional convenience for the disabled traveller.

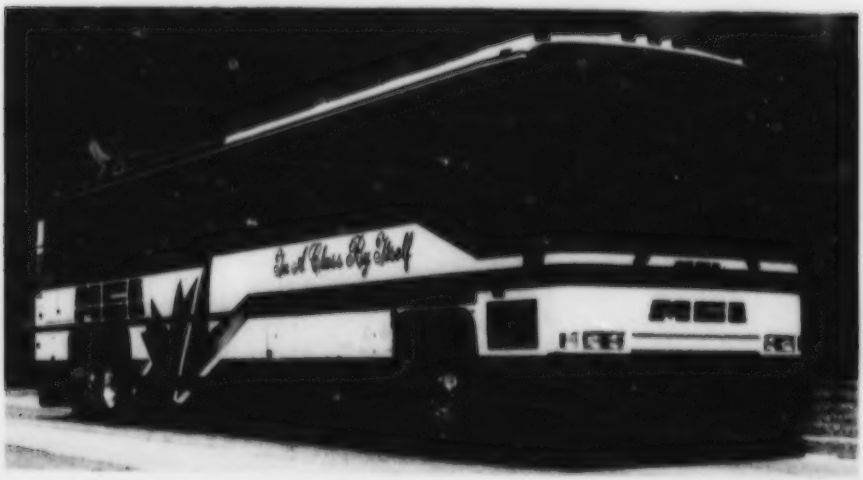
The prototype coach has 47 seats, some of which fold and slide to create space for wheelchair tie-downs. With a conventional lavatory, the coach could seat up to 59 passengers.

The bus is now being demonstrated to provincial authorities, coach operators, and representatives of the disabled community across Canada.

Contractor: Motor Coach Industries, Winnipeg, Manitoba
Report: None to date
Schedule: October 1987 - September 1990
Funding:

Motor Coach Industries	$2 000 000	(approx.)
Supply and Services Canada	$473 633	
Energy R&D Program	$240 000	
TDPP	$145 500	
TDC	$100 867	
Total	$2 960 000	

Project Number: 6978
File Number: 1465-472-3
Project Officer: Brian Marshall



Internal elevator lift

Intercity bus service demonstration

This three-year demonstration, inaugurated in October 1989, is offering fully integrated accessible bus service on Canada Coach Lines' regular service routes connecting Niagara Falls, St. Catharines, Hamilton, Cambridge, and Kitchener-Waterloo. Endorsed by the Canadian Bus Association, the demonstration will provide comprehensive data on market potential and economic viability that will apply to corridors throughout Canada. With up to seven return trips daily, the service links five communities with local parallel transit systems. Passengers can call a toll-free number to receive route information, make a reservation, and plan their itinerary. The buses, built by Motor Coach Industries of Winnipeg, are equipped with internal elevator lifts, wheelchair tie-down stations, and aids for sensory-impaired passengers.

Transport Canada is helping to finance the purchase of six of these new lift-equipped vehicles for the service through a contribution agreement. Canada Coach Lines is responsible for all operating costs and will collect detailed utilization and cost data during the demonstration. TDC has contracted Delcan Corporation to coordinate, monitor, analyse, and evaluate the service.

Contractors: Canada Coach Lines, Hamilton, Ontario, and Delcan Corporation, North York, Ontario
Report: None to date
Schedule: April 1988 - March 1993
Funding:

TDPP (Canada Coach Lines)	$1 185 000
TDPP (Delcan Corporation)	$ 261 973
Total	$1 446 973

Project Numbers: 7064, 7119, 7382
File Number: 1465-525
Project Officer: Brian Marshall

GSM taxi

Accessible taxi development

TDC is supporting several projects designed to provide elderly and disabled passengers with access to urban taxi transportation. The work has indicated a demand for such service and has defined how it could be operated by conventional taxi companies.

A demonstration service of accessible taxis in Ottawa is using four taxivans equipped with wheelchair ramps and specifically designed to accommodate other passengers as well as persons in wheelchairs. Preliminary project findings indicate that retrofitting current equipment does not meet the exacting demands of taxi operations; that driver selection and training are crucial; and that, for the service to be viable, operators require some form of subsidy.

The demonstration has provided input for a project to develop a Canadian-made taxi expressly to accommodate both disabled and other passengers. Designed and manufactured by GSM Design, the vehicle is attractive to taxi operators in terms of cost and ease of operation. This vehicle will be one of six in a series of taxi demonstrations in Quebec.

TDC will also work with Quebec's ministry of transportation to develop a training package designed to sensitize taxi drivers to the needs of elderly and disabled passengers.

Contractor: Ministry of Transportation of Ontario, Downsview, Ontario
Report: None to date
Schedule: April 1989 - May 1991
Funding:

TDPP	$207 000
Ministry of Transportation of Ontario	$133 000
Total	$340 000

Project Number: 7304
File Number: 1450-103-87
Project Officer: Trevor N. Smith

Contractor: GSM Design Inc., St. Laurent, Quebec
Report: None to date
Schedule: January 1990 - December 1990
Funding:

GSM	$120 000	(in-kind)
TDPP	$115 000	
TDC	$63 000	
Total	$298 000	

Project Numbers: 7367, 7368
File Number: 1450-103-101
Project Officer: Trevor N. Smith

Two types of accessible taxis operated in the Ottawa demonstration

Boarding wheelchair passengers at small airports

While Transport Canada's major airports are fully accessible to physically disabled persons, wheelchair passengers encounter difficulty in boarding aircraft at smaller airports where there are no loading bridges from the terminal to the aircraft. Since mobility disabled persons are travelling in greater numbers, the need for an effective boarding system for wheelchair passengers is pressing.

An earlier TDC project found that the most promising and acceptable boarding method in the absence of a loading bridge from the terminal to the aircraft is an enclosed pallet carried by a forklift truck.

Following preliminary trials, a prototype pallet boarding device was modified to meet the requirements of the airlines. The first operational evaluation is taking place at Fredericton airport, and other demonstrations are planned.

Contractor: W.R. Davis Engineering Ltd., Ottawa, Ontario
Report: None to date
Schedule: November 1989 - October 1990
Funding: TDPP $109 689
Project Number: 7014
File Number: 1450-103-37-3
Project Officer: Roy S. Nishizaki

Enclosed pallet for boarding wheelchair passengers

Accessibility of small aircraft

As the number of commuter, regional, and feeder airlines increases in Canada, wheelchair access to aircraft with fewer than 60 seats has become increasingly important. In this project researchers studied current boarding procedures and equipment and developed several concepts for boarding systems that would overcome the constraints of the physical dimensions and configurations of the six most frequently used small aircraft in Canada.

A stairway with an integrated lift proved the most promising concept. The wheelchair traveller uses the lift to reach the aircraft door, while other passengers can board by the stairs (which are part of the device). The equipment is simply designed and operated, requires few modifications to the aircraft, and allows the free movement of all passengers. The challenge now is to devise a specialized boarding chair that can negotiate the extremely narrow aisles of commuter aircraft.

The results of this study will help Transport Canada's air policy branch to develop accessibility standards for small aircraft. In addition to its domestic consultations, TDC will continue to participate in the U.S. Federal Aviation Administration's Working Group consultations on level-change devices and a commuter aircraft boarding chair.

As a follow-on to this project, TDC evaluated a prototype integrated platform lift, developed privately by Mid-Canada Equipment Sales of Winnipeg, to determine its mechanical and ergonomic suitability. This firm used the results of the evaluation to improve the prototype and tested it in various carriers. Carter Aero of Minneapolis, Minnesota, is planning to manufacture the lift in Winnipeg.

Contractor: James F. Hickling Management Consultants Ltd., Ottawa, Ontario

Report: TP 9566E, Accessibility of small aircraft to disabled travellers: preliminary design study, James F. Hickling Management Consultants Ltd., 1988

Schedule: November 1987 - May 1989

Funding: TDPP $46 000

Project Number: 6967

File Number: 1450-103-83

Project Officer: Barbara A. Smith

Pre-production integrated platform lift

Ferry accessibility

This project evaluated the accessibility of two federally subsidized ferries (the *Prince Nova* and the *Prince Edward*) and the terminals from which these vessels sail (the Caribou Terminal in Nova Scotia and the Wood Islands Terminal in Prince Edward Island).

The project's principal objective was to develop concepts for a level-change system for boarding and between-deck transfers of elderly and disabled passengers.

Three concepts – a shipboard elevator and wheelchair lift system, a dockside elevator system, and a dockside ramp system – were developed and evaluated on the basis of cost, integration, operational considerations, safety, and suitability for disabled users.

The shipboard elevator and wheelchair lift system, selected as the most advantageous, would provide access from the vehicle deck to the mezzanine deck by a wheelchair lift, and a cable suspension configuration or a hydraulically operated elevator would permit access from the mezzanine to the promenade and bridge decks. Projected usage rates indicate that no additional crew members would be needed to operate the proposed system.

The implementation of the recommended system, including detailed design, construction, installation, and evaluation, is planned for later phases of the project.

Contractor: W.R. Davis Engineering Ltd., Ottawa, Ontario
Report: TP 10376E, Development of a level change system for federally subsidized vessels. Phase I – problem definitions/concept development, W.R. Davis Engineering Ltd., 1990
Schedule: March 1989 - May 1990
Funding: TDPP $48 217
Project Number: 7158
File Number: 1450-103-96
Project Officer: Barbara A. Smith

***The* Prince Edward**

Prototype automobile driving simulator

This project is further developing and evaluating a prototype driving simulator developed by Concordia University with TDC support. The work responds to the need for a low-cost, effective means of evaluating and training drivers who have suffered brain damage.

The interactive simulator has been equipped to assess the readiness of brain-damaged, elderly, and cognitively impaired individuals to return to driving or take on-the-road training. The system uses relatively inexpensive microcomputer technology to model a vehicle's dynamics. A graphics station translates data from the model into real-time graphics presenting realistic road conditions while sensory modules simulate visual, tactile, and acoustic effects. The simulator uses magnetoencephalographic/electroencephalographic (MEG/EEG) techniques, developed by Applied Brain Behaviour Systems of Vancouver, with a human information-processing model. MEG data, obtained in the laboratory, tell researchers where to place electrodes to obtain the EEG data for developing assessment procedures and conducting tests.

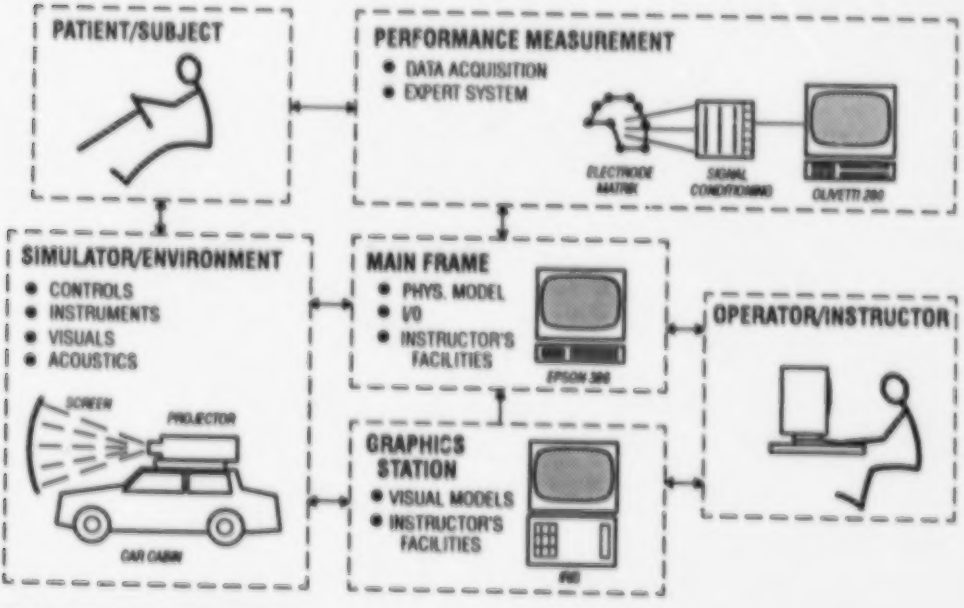
The three current phases of the work will develop rear view and peripheral visuals, produce a comprehensive set of assessment protocols, and conduct field evaluations at several rehabilitation centres.

The work has excellent potential for transfer to other areas of interest to Transport Canada, such as pilot or air traffic controller selection and training. There is also considerable interest in marketing specially adapted simulators for such applications as driver training and pharmacological research.

Contractor: Mechanical Engineering Department, Concordia University, Montreal, Quebec
Report: None to date
Schedule: January 1990 - December 1992
Funding:

TDPP	$330 000
TDC	$310 851
Total	$640 851

Project Numbers: 7387, 7388
File Number: 1450-103-77-2
Project Officer: Ruth M. Heron



Driving simulator configuration

Standards for transportable wheelchairs

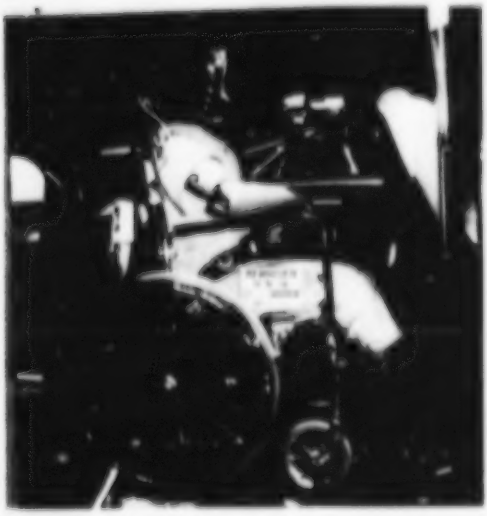
The development of standards for all components of a wheelchair occupant protection system represents the culmination of TDC's efforts in this area. Earlier work included studies on wheelchair securement systems in vans and mini-buses, the ergonomic evaluation of modified standards, and recommendations on the in-flight cabin storage of wheelchairs.

The Canadian Standards Association (CSA) is working with the provinces of Ontario, British Columbia, Alberta, and Quebec to develop the standards. The project includes wheelchair securement/passenger restraint, transportable wheelchairs, and the revision of the current published standards for public vehicles used to transport disabled persons. Dynamic testing of equipment is integral to this work; for example, three-wheeled scooters will be subjected to severe driving and manoeuvring conditions.

The participation of the Canadian Urban Transit Association will ensure that the voice of the Canadian transit industry is heard, and will also help to lay the groundwork for the acceptance and adoption of the standards by all the provinces and by transit operators. Broad national representation and participation should result in a stronger case for the adoption of the standards throughout Canada, and, subsequently, in safer travel for elderly and disabled persons.

The existence of standards would provide guidelines for manufacturers in designing new products. They would also be a significant contribution to the development of worldwide standards by the International Standards Organization. Once the CSA publishes the standards, the process of adoption and regulation is the responsibility of provincial authorities. If adopted nationally, they would make Canada a world leader in this field.

Contractor: Canadian Standards Association, Rexdale, Ontario
Report: None to date
Schedule: November 1989 – March 1992
Funding: TDPP $120 000
Project Number: 7472
File Number: 1450-103-92
Project Officer: Barbara A. Smith



Dynamic testing of wheelchair securement and passenger restraint

Subway communication system

This project is developing a prototype electronic display communication system that provides both auditory and visual information. Designed to respond to the needs of elderly and disabled passengers, the Integrated Communication, Information, and Security System (ICISS) can be used to display station stop announcements, public and emergency information, and advertising messages to subway passengers.

Although the project is studying the use of ICISS in Montreal's subway system, the technology could be applied to other modes of transportation. The system hardware consists of three-colour, high intensity LED panels, capable of displaying both images and text. These displays are driven remotely from a central point. The system can also digitize, store, and replay specific audio messages.

The first phase of the project, an evaluation of the feasibility of implementation, has been completed. Sessions were conducted to assess the reactions of elderly and disabled passengers and a control group. The contractor also carried out an ergonomic review of the system design. Results indicated that there were no technical barriers to implementation, and response from user groups was very favourable.

The second phase, now under way, involves the development and production of a full-mission prototype to be demonstrated in the Montreal subway system in the summer of 1991.

Contractor: Télécité Inc., Pointe Claire, Quebec

Report: Non-releasable, contains proprietary commercial information

Schedule:
(Phase I) September 1989 - March 1990
(Phase II) June 1990 - December 1991

Funding:

PHASE I	
Télécité inc.	$150 000
TDPP	$30 000
TDC	$30 000
Total	$210 000
PHASE II	
Télécité Inc.	$400 000
TDPP	$200 000
TDC	$65 000
Ministère des Transports du Québec	$42 500
City of Montreal	$42 500
Total	$750 000

Project Numbers:
(Phase I) 7384, 7385
(Phase II) 7605, 7606

File Number: 1450-103-71

Project Officer: Trevor N. Smith

Artist's drawing of Montreal subway car with passenger communication system shown at left

HandyLine demonstration

HandyLine is a prototype automated telephone information system that uses touch-tone technology and computer-generated voice communication to allow callers to interact with a computerized data base.

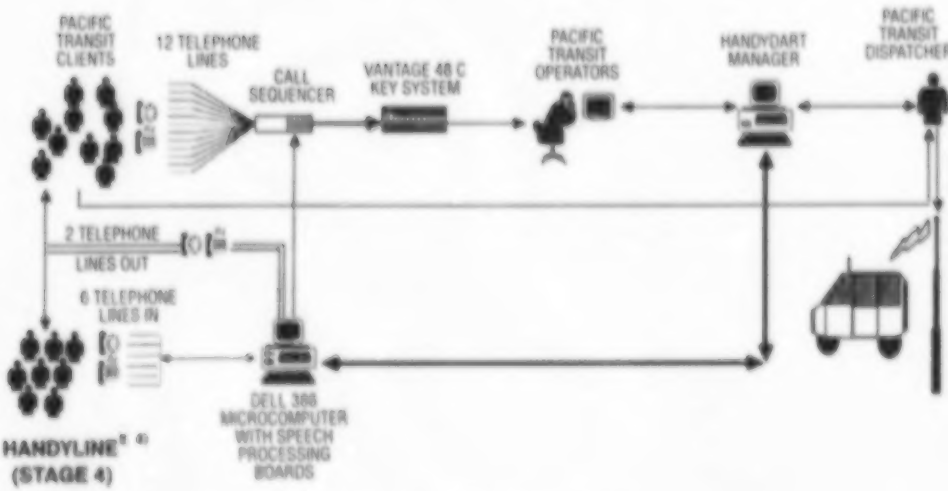
This project, aimed at demonstrating and evaluating the reaction of disabled clients in the Vancouver area to the technology, uses the TDC-sponsored Integrated Transportation Information System, ITIS. Developed by Oracle Communications Inc. of Burnaby, B.C., ITIS has already been successfully applied to aviation weather broadcasts, airport information systems, and urban transit (see page 104). Initial work modified ITIS in order to develop a system compatible with the computer-assisted scheduling procedures of special transit service operators.

The system will assist paratransit systems to reduce their labour costs and provide prompter service by automating routine telephone inquiries and services. It will also handle outbound reminder calls to clients with a view to reducing "no shows" and boarding delays. Disabled passengers will benefit by being able to reserve or cancel trips without operator assistance.

HandyLine can also be used as a management tool to provide general information about the service. For example, it will keep records of the total number of calls by type of inquiry.

An evaluation of the initial stage of implementation by disabled users and dispatching staff has demonstrated the system's acceptability.

Contractor: British Columbia Transit, Vancouver, B.C.
Report: None to date
Schedule: January 1990 - January 1992
Funding: TDPP $182 145
Project Number: 7400
File Number: 1450-103-102
Project Officer: Ling Suen



Proposed system configuration when HandyLine is fully implemented

Data base for elderly and disabled Canadians

In this project researchers are compiling North America's most comprehensive data base on transportation and disability. Characterizing the transportation and socio-economic patterns of elderly and disabled Canadians, this national information base will include geographic areas, types of disability, travel patterns, and modes of transportation, as well as comparisons with the general population and predictions on the future population of disabled persons.

The major source of data is Statistics Canada's Health and Activity Limitations Survey, conducted following the 1986 national census. The contractor will supplement this data with results from several other surveys undertaken in North America over the last decade.

Through TDC, the information base will be available to consumer groups, government agencies, researchers, and carriers, enabling them to analyse the limitations on transportation of various disabled groups, to develop policies, and, ultimately, to improve the accessibility of the transportation system.

The contractor will also make recommendations for R&D and policy options for various levels of government, based on this project's unique market research.

Contractor: James F. Hickling Management Consultants Ltd., Ottawa, Ontario
Report: None to date
Schedule: July 1988 - March 1991
Funding:

TDPP	$177 821
TDC	$126 728
Total	$304 549

Project Numbers: 7045, 7233
File Number: 1450-103-14
Project Officer: Trevor N. Smith

Researchers are collecting information on transportation services for elderly and disabled travellers in Canada.

Intercity travel and the blind or deaf traveller

Disabled persons' access to transportation has received increasing attention in recent years. Much funding and research have been directed toward removing architectural barriers for the mobility impaired. However, less work has been done on access for sensory impaired Canadians.

Two projects addressed access for travellers with visual or hearing impairments. Their scope was limited to transportation terminals, but the broader recommendations could be applied to all environments.

An extensive study by the Canadian National Institute for the Blind summarized the various visual impairments, explained how the visually impaired travel, and described the aids available to them. Accessibility standards of various building codes were examined and general design guidelines presented. Specific recommendations were made for interior and outdoor features, including entrances, stairways, doors, and elevators.

In the second study, the Canadian Hearing Society analysed the current state of accessibility for deaf and hard of hearing travellers in air, rail, bus, and ferry terminals. The society recommended the development of suitable standards for signage; the continuing development of promising communication technologies such as TDC's Communicaid, Translaid, and ITIS; and the standardizing of communications features and facilities in terminals. It also stressed that staff should be trained to develop awareness and to communicate appropriately with this group.

Both studies were widely distributed to engineers, architects, and urban planners, and should help to reduce the barriers to mobility faced by visually and hearing impaired travellers in transportation terminals.

Contractor: Canadian National Institute for the Blind, Toronto, Ontario

Reports:
TP 9048E, Access needs of blind and visually impaired travellers in transportation terminals: a study and design guidelines, Canadian National Institute for the Blind, 1987

TP 10067E, Design guidelines for meeting the access needs of blind and visually impaired travellers in transportation terminals, Canadian National Institute for the Blind, 1989

Schedule: May 1987 - January 1989

Funding: TDPP $44 726

Project Number: 6887

File Number: 1450-103-85

Project Officer: John H. Morgan

Contractors: The Canadian Hearing Society and The Behavioural Team, A Corporation, Toronto, Ontario

Report: TP 9839E, Intercity travel and the deaf and hard of hearing traveller: an analysis of the current state of accessibility, The Canadian Hearing Society and The Behavioural Team, A Corporation, 1989 *(available on audiotape)*

Schedule: April 1988 - April 1990

Funding: TDPP $50 000

Project Number: 7059

File Number: 1450-103-91

Project Officers:
John H. Morgan, Barbara A. Smith

Access to transportation terminals for visually and hearing impaired travellers is the focus of recent TDC studies.

Meeting the needs of cognitively disabled travellers

This study analysed the difficulties that passengers with cognitive or emotional disabilities encounter when using public transportation. Conducted by a project team representing the disciplines of applied psychology, clinical/forensic psychology, ergonomics, law, and social work, it was TDC's first examination of the needs of this diverse group.

The investigation included the preparation of a lexicon of acceptable terminology, the classification of mental disorders, a review of pertinent legal issues, an analysis of demographic data to characterize the target market, and a survey to determine the demand for transportation and the problems encountered.

The team concluded that persons with disabilities in the mid-range of severity would benefit most from transportation accessibility initiatives. They noted that adaptive strategies can help to overcome certain limitations — for example, travellers who have difficulty reading can learn to orient themselves by using landmarks. Problems were most prevalent in terminals, followed by on-board aircraft, intercity buses, and trains.

The researchers made recommendations for personnel training, user training, special customer services, and improvements to procedures and design of information. They also identified a number of areas for further investigation.

Contractor: The Behavioural Team, A Corporation, Toronto, Ontario

Report: TP 10450E, Flight 201 has been moved to Gate 102: challenges experienced by travellers with cognitive or emotional disabilities, The Behavioural Team, A Corporation, 1990 *(available on audiotape)*

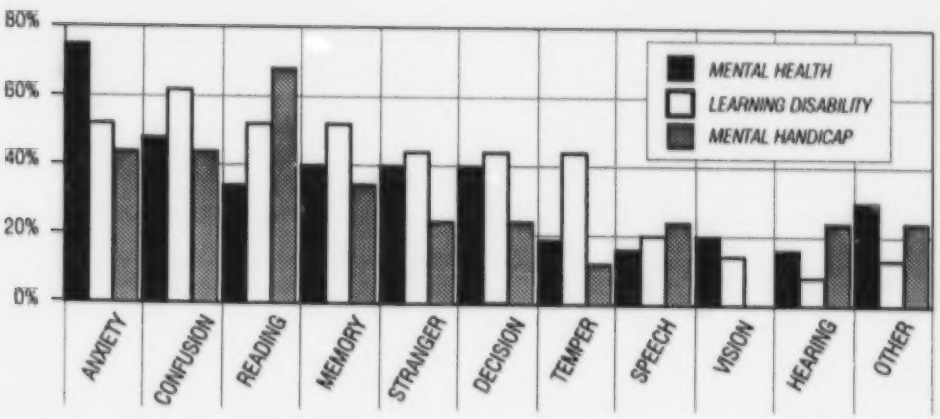
Schedule: February 1989 - May 1990

Funding: TDPP $57 000

Project Number: 7176

File Number: 1450-103-95

Project Officer: Barbara A. Smith



Prevalence of functional limitations that create travel difficulties

Analysis of traveller information technology

Adequate information for travellers is essential to all transportation modes. Canada has spent approximately $10 million developing and implementing new information and communication technologies. While government and industry have allocated significant resources to such development, little or no research has been done on travellers' comprehension of information, on the ergonomic aspects of the relationship between these new technologies and users, or on their effect on ridership. In particular, the relationship between information systems and specific market groups, such as disabled travellers, has never been analysed.

Recognizing this gap, TDC commissioned a study of existing traveller information and communication systems to assess, from an ergonomic point of view, their effectiveness in specific market segments.

Discussions were held with passenger groups with physical, visual, hearing, or cognitive disabilities. Researchers reviewed existing traveller information systems, defining their requirements, identifying current deficiencies, and outlining opportunities for improvement.

The study identified several important issues: the need for information in a multi-media format, such as a visual display coupled with auditory messages; the need to make travel information accessible to passengers with disabilities, through thoughtful design of video terminals, information maps, signage, and way-finding and orientation cues; and the need for personnel training, in particular the training of carrier personnel to assist with guide dogs and wheelchairs.

Contractor: TransVision Consultants Ltd., North Vancouver, B.C.
Report: TP 10023E, Ergonomic assessment of information and communication systems for travellers with disabilities, TransVision Consultants Ltd., 1989
Schedule: May 1988 - November 1989
Funding: TDPP $59 800
Project Number: 6989
File Number: 1450-103-89
Project Officer: Ling Suen

Communicaid information kiosk at Vancouver International Airport

REPORT LISTING

The following is a list of TDC reports published since the previous edition of the project directory. These reports are available free from TDC while supplies last.

An annual list of the Centre's reports is given in *TDC Publications*, TP 2602, available on request from TDC.

Reports may be borrowed through interlibrary loan from the Judith Nogrady Library at TDC in Montreal or from Transport Canada Library and Information Centre, Transport Canada Building, 2nd floor, Ottawa, Ontario K1A 0N5.

In addition, photocopies and microfiches of out-of-print reports are available at various charges from Micromedia Ltd., 165 Hotel de Ville, Hull, Quebec J8X 3X2; telephone: 1 (800) 567-9669 (Maritimes, Ontario, Quebec), 1 (800) 567-1914 (Western provinces); fax: (819) 770-9265.

Marine Transportation

Analysis of corrosion data to develop operational and engineering criteria for Arctic structures, volume I, T.G. Brown and V. Laskow, F.G. Bercha and Associates (Alberta) Ltd., April 1989. TP 9681E

Arctic marine radar development, phase I: selection of host marine radar, Charles Gautier, Canarctic Shipping Company Ltd., January 1990. TP 10105E

Arctic temperature & wind conditions related to ship-hull steel, J.B. Maxwell, Atmospheric Environment Service, Environment Canada, May 1989. TP 3702E

Conférence internationale sur la technologie du coussin d'air : 27-29 septembre 1988 – Compte rendu / Joint International Conference on Air Cushion Technology: September 27-29, 1988 – Proceedings, édité par / edited by T. Gillies, Communications Gillies Inc., janvier / January 1989. TP 8979

Déglaçage, exploitation par temps froid, véhicules / Icebreaking, cold weather operations, vehicles, communications reçues / collected papers, édité par / edited by M.J. Hinchey, Memorial University of Newfoundland, septembre / September 1989. TP 8979

Design and application of strakes on a Canadian Coast Guard ship, John E. Carter, Kristi Maritime Inc., September 1990. TP 10553E

Design, construction and testing of an Arctic survival sled, R.A. Dick and M. Kalisiak, Melville Shipping Ltd., September 1988. TP 9466E

Desserte maritime de l'archipel de Montmagny, P.E. Barbeau, Navtech Inc. et le Conseil économique de la Côte-du-Sud, juin 1990. TP 10375F

Development and evaluation of a shipboard integrated navigation and display system, Offshore Systems Ltd., November 1988. TP 9696E

Development of a level change system for federally subsidized vessels, phase 1: problem definition/ concept development, A.J. Coppens, D. Vandam, and P. Bolloni, W.R. Davis Engineering Ltd.; R. Rutherford and G. Paterson, German and Milne; and F. Ginpil, Humantech Inc., May 1990. TP 10376E

Development of a procedure for predicting propeller-ice interaction forces, M.W. Chernuka, R.P. Jategaonkar, M.E. Norwood, et al., Martec Ltd., May 1989. TP 9850E

Development of a research plan for the full-scale testing, data analysis, and modeling of the propulsion train of a class IV icebreaker with nozzle propellers, D.N. Bruce Cowper, Fleet Technology Ltd., June 1989. TP 8015E

Development of a system of computer models for the design and evaluation of ice class shafting and propeller systems, D.N. Bruce Cowper and Arthur Karton, Fleet Technology Ltd., January 1989. TP 9647E

Development of Canadian and international manoeuvring standards, S. Lantos and A. Kendrick, German & Milne Inc., January 1989. TP9551E

Effect of parallel midbody on the resistance of ships in level ice, D.N. Baker, R.A. Dick, and R.B. Paterson, Melville Shipping Ltd., March 1988. TP 9242E

Evaluation of a simplified ridge modelling method, two volumes, G. Comfort and R. Abdelnour, Fleet Technology Ltd., May 1990. TP 10202E

Experimentation with various methods of de-icing and anti-icing for ships, R.A. Dick and M. Kalisiak, Melville Shipping Ltd., September 1989. TP 9948E

Feasibility of using segmentation techniques for the enhancement of marine radar images as encountered in ice infested waters, Fayçal Kahloun and Ajit Nilakantan, Cimmetry Systems Inc., July 1989. TP 9832E

Field evaluation of TDC/INTERA Marine-Vue upgrades, Robert Gorman, Canarctic Shipping Company Ltd., March 1989. TP 9780E

Full-scale tests on the response of ice strengthened propeller blades to ice loads, P.A. Spencer and Vlodek Laskow, two volumes, Geotechnical Resources Ltd., March 1989. TP 9668E

Functional specifications for second-generation ice navigation system, Charles Gautier and Robert Gorman, Canarctic Shipping Company Ltd., July 1990. TP 10565E

Further development of shipboard fibre optic standards, J.S. Mayich, Focal Technologies Inc., September 1989. TP 10026E

Helicopter radar report, R.T. Lowry, Intera Technologies Ltd., September 1990. TP 10498E

Icebreaker design synthesis analysis of contemporary icebreaker performance, A.J. Keinonen, R.P. Browne, and C. Revill, Arno Keinonen Arctic Consulting Inc., September 1989. TP 9992E

Icebreaker midbody resistance, phase II: beam variation, D. Baker and C. Mulder, Melville Shipping Ltd., January 1990. TP 10161E

Icebreaking, cold weather operations, vehicles / Déglaçage, exploitation par temps froid, véhicules, collected papers / communications reçues, edited by / édité par M.J. Hinchey, Memorial University of Newfoundland, September / septembre 1989. TP 8979

Ice flow and blockage investigation of shrouded propellers, V. Laskow, Arctic Research and Development Ltd., December 1988. TP 9640E

Ice propeller interaction forces, two volumes, A.J. Keinonen and R.P. Browne, Arno Keinonen Arctic Consulting Inc., April 1990. TP 10401E

Ice strength indexer, phase III, D.N. Baker, Melville Shipping Ltd., March 1990. TP 10486E

Joint International Conference on Air Cushion Technology: September 27-29, 1988 – Proceedings / Conférence internationale sur la technologie du coussin d'air : 27-29 septembre 1988 – Compte rendu, edited by / édité par T. Gillies, Communications Gillies Inc., January / janvier 1989. TP 8979

Modification and testing of a segmented model of an icebreaker to evaluate ice resistance mathematical models, I.F. Glen, R. Abdelnour, and M. Steele, Fleet Technology Ltd., March 1989. TP 9849E

Nav-Ice/Marine-Vue Integration, R.T. Lowry, J.G. McAvoy, Intera Technologies Ltd., March 1989. TP 10032E

Organisation temporelle du travail sur les navires de la Garde côtière canadienne : impacts physiologiques et psychologiques, René Boulard, Marie-Alice Telle-Lamberton et Michel Vézina, GIROSST, septembre 1989. TP 10048F

Parametric study of icebreaking bow forms, Donald Carter, Donald Carter & Associates, March 1990. TP 10193E

Precise radar integrated navigation system (NAVFIX) for coastal and inshore navigation, R.G. Lyall and H.H. Lanziner, Offshore Systems Ltd., December 1988. TP 9728E

PRICI – an analytical propeller/ice interaction model, D.N. Baker, Melville Shipping Ltd. and V. Laskow, Arctic Research and Development Ltd., July 1990. TP 10634E

Radar data gathering on M.V. *Arctic*, Charles Gautier, Canarctic Shipping Company Ltd., February 1990. TP 10156E

Results of comparative model tests with a conceptual hull form and the original R-class icebreaker, Donald Carter, Donald Carter & Associates, November 1990. TP 10617E

Search and rescue experiment to derive leeway and drift rates for common search and rescue objects, Notre Dame Bay, Newfoundland, summer 1989, Reg Fitzgerald, John Russell, and Don Bryant, Nordco Ltd., March 1990. TP 10221E

Search and rescue target detection experiment – Canso Bank, 1987, B.R. Dawe, D. Finlayson, and D. Bryant, Nordco Ltd., September 1988. TP 9475E

Search and rescue target detection experiment – Canso Bank, 1988, B.R. Dawe, D. Bryant, and D. Finlayson, Nordco Ltd., October 1989. TP 10078E

SINSS ice navigation console, phase II: console implementation and bridge upgrade, Charles Gautier, Canarctic Shipping Company Ltd., November 1989. TP 10044E

Ship structures research in Canada: the development of a practical program and management approach, I. F. Glen, May 1990. TP 10456E

Star-Vue interactive assistance, J.G. McAvoy, Intera Technologies Ltd., March 1990. TP 10406E

Study on hull corrosion and coatings, B.H. Levelton, B.H. Levelton & Associates Ltd., October 1988. TP 9493E

Verification through field measurements of the extent of reduction in icebreaking resistance for icebreaking strakes, D.N. Bruce Cowper and Ron Ritch, Fleet Technology Ltd., August 1990. TP 10554E

Work scheduling on Canadian Coast Guard ships: physiological and psychological impacts, René Boulard, Marie-Alice Telle-Lamberton, and Michel Vézina, GIROSST, September 1989. TP 10048E

Air Transportation

An airspace design system using a graphics workstation: the pilot project, Lily Lam and Denis Leclerc, Virtual Prototypes Inc., September 1988. TP 9601E

Analysis of runway roughness, David K. Hein and Michael H. MacKay, John Emery Geotechnical Engineering Ltd., March 1989. TP 9718E

Application of linear induction motor in-track technology at airports, G.L. Allen, S. Beninger, and D.N. Ference, UTDC Inc., April 1989. TP 10195E

A computer-assisted X-ray screening system, T. Feather, A. Lee-Kwen, L. Guan, et al., Array Systems Computing Inc., and M. Macecek and D. Allan, Techno-Scientific Inc., July 1990. TP 10065E

Conférence internationale sur la technologie du coussin d'air : 27-29 septembre 1988 – Compte rendu / Joint International Conference on Air Cushion Technology: September 27-29, 1988 – Proceedings, édité par / edited by T. Gillies, Communications Gillies Inc., janvier / January 1989. TP 8979

CORES: air traffic conflict resolution system, I.G. Smith, C.A. Crabb, G.R. Ram, et al., CompEngServ Ltd., October 1989. TP 9990E

Design of an automatic passenger counting/tracking system for airports, Pierre Chénier and Michel Barré, DTI Télécom Inc., March 1989. TP 9646E

Development of an operations simulator for evaluation of ATCS modules, G.W. English, Canadian Institute of Guided Ground Transport, Queen's University, October 1988. TP 9540E

Développement d'un système expert pour les prévisions météorologiques des aéroports, Yves Chartier, Michel Desmarais, Peter Zwack, et al., Centre de recherche informatique de Montréal, février 1990. TP 10204F

Ergonomically designed workstation for training of electronic systems maintenance technicians, two volumes, John Spacek, Michael Gurstein, Jean-Marc Robert, et al., Sypher:Mueller International Inc., June 1988. TP 8742E

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